Risø annual report 1999

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Risø Annual Report 1999

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Wind energy with the wind in its sails

BOYE KOCH

The new Windows version of Risø's WAsP program is selling well. WAsP is considered the industry standard in the field of wind resource assessment and siting of wind turbines. Pictured here are three of the scientists behind the WAsP success story: From the left senior research fellow Niels Gylling Mortensen, Head of Department Erik Lundtang Petersen and Head of Programme Lars Landberg.

The success of the Danish wind turbine industry has led to an increased need for testing larger and larger blades and wind turbines. The blades are tested at Risø's facility at Sparkær, Jutland, where a large new foundation for 30–50m blades has been put into service in 1999 and the first 35m blades have been tested. In many cases, blade measurements are made in the field where the blade manufacturer assembles the blades on their own test stand and Risø takes readings on site. First of all, static load readings of the blades are taken. Then the blades are put into heavy-duty vibrations, where they have to withstand five million vibrations in order to pass the test. Both types of measurements are carried out edgewise and flapwise. Edgewise loads are mainly due to the force of gravity and occurs in the direction of motion of the blade. Flapwise loads are mainly due to the turbulent effect of the wind on the blade and occurs in the wind direction. Wind turbine tests are undertaken in such diverse locations as Jutland, Spain and California. Measurements are taken by means of approx. 30 sensors fitted to the wind turbine. All wind data are measured simultaneously at meteorological masts erected close to the wind turbines.

WAsP – Wind Atlas Analysis and Application Program – is the world's leading calculation program in the area of wind resources and the siting of wind turbines. The program, developed by Risø, was introduced in 1987. It has now been sold to more than 500 users in more than 70 countries. The first Windows version was released in March 1999. It was launched at the major European wind energy conference in Nice and sales have grown steadily ever since. In 1999 alone, 190 software packages were sold.

A boost for Danish polymer research

BOYE KOCH

DTU and Risø have established a joint Danish Polymer Centre, taking its cue from recommendations in the national strategy on materials research. The centre manager, Ib Johannsen, pictured on the right, with engineering assistant Kai Stoffregen at one of the centre's large injection moulding machines.

The Danish Polymer Centre aims to create new development opportunities for the education of Danish scientists and for Danish industry. During 1999, a new, expanded joint venture has been established between Risø and DTU. The centre is aiming for an annual turnover of approx. DKK 40 million. One-half of this comes from the host institutions. A quarter will come in the form of grants from Danish research councils as part of the national

strategy on materials research. The remaining quarter will be financed via collaboration contracts, EU projects, industrial contracts and sponsors, etc. The centre will provide considerable long-term bolstering for Danish polymer research, leading to new development opportunities for industrial exploitation of polymers. The centre will also co-ordinate the training of scientists as well as graduate and diploma level education schemes in the area of polymers. One of the hallmarks of the Danish Polymer Centre is its interdisciplinary nature.

BOYE KOCH

The Danish Polymer Centre is enjoying a fresh start in newly refurbished premises at DTU. Centre manager Ib Johannsen is pictured here in one of the polymer centre's new process halls at DTU during renovation at the beginning of 2000.

Breakthrough in the drive to explain superconductivity

BOYE KOCH

New results achieved at Risø make a vital contribution to theory formulation with regard to superconductivity. Pictured here is researcher Kim Lefmann, busy assembling the crystals of the superconducting material resembling thin black pencils in the neutron spectrometer at Risø's research reactor DR3.

Superconductors are materials that, when cooled to sufficiently low temperatures, conduct electrical current without resistance. Even the best superconductive materials today have to be cooled to below 100 degrees C. Understanding the basic mechanism behind superconductivity could perhaps pave the way for designing materials that are superconductive even at room temperature. That would have enormous technological and environmental advantages, e.g. cables capable of carry electricity with no loss of energy.

Current is in fact the carrying of an electric charge, almost always via the electrons in the material. Electrons have another property as well: their spin. It is as if each electron is a little bar magnet pointing either up or down. Risø scientists have carried out neutron scattering experiments on large single crystals of a copper oxide high-temperature superconductor. These experiments only investigate the spin of the electron. On comparison with experiments to study the charge of the electron, it emerges that the electrons are apparently "dissolved" inside the copper oxide layers of the superconductor: their spin and charge move independently. This important result, achieved through extensive international collaboration, has provided theoretical physicists with important new input to their deliberations on the workings of superconductivity.

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New knowledge for Risø's customers

Risø's management performance contract 1998–2001 contains a number of objectives for expanding our dialogue and joint ventures with industry, the academic world and governmental authorities. This annual report illustrates how the work of fulfilling the objectives of the contract have produced results that may open new technological perspectives.

In 1999, we made special efforts to reach Danish industry by means of consultancy or sale of research and development, licences, apparatus, etc. This part of our operations enjoyed considerable success, with income increasing by approximately 20% to DKK 70 million.

Success was particularly apparent in the area of wind energy, which also made its mark on 1999 in other ways. Risø helped to organise an international wind energy conference in Nice and has entered into a new collaboration agreement on international certification and approval of wind turbines with Det Norske Veritas. A new test stand was inaugurated at Risø's wind blade testing facility at Sparkær in Jutland and good progress was made towards the establishment of a new testing station for large wind turbines in an area north of Nissum Fjord. Finally, Risø's Board has approved the establishment of a wind energy centre at Risø supported by the Ministry of Research.

Prominent among other examples of how Risø's research is reaching Danish industry is the establishment of the Danish Polymer Centre and the formation of three centres for miniaturisation of optical sensors, monitoring of industrial processes and systems and surface metrology and functionality, respectively, all three centres having the participation of a number of private companies and several GTS institutes. It should also be noted that Risø is a co-founder of the major new centre for biotechnology at the University of Copenhagen, *Biotech Research & Innovation Centre (BRIC)*, expected to be completed in 2003.

Centres like these are one of many channels for transferring new knowledge and technology. Risø has developed various modes of transfer, described in a recently-published booklet *"2 x 4 opportunities for Danish companies"*. We emphasise flexibility in relations with industry, but our goal is that the different types of collaboration should be of benefit to all parties concerned and cater for their various needs, including the needs of private companies for discretion and the research institutions' need to publish.

This dichotomy was the subject of a public debate at the end of 1999 on publication versus confidentiality of research results, in which Risø emphasised the need to find the most appropriate form of collaboration on a case by case basis and generally to take great care in formulating the underlying agreements.

Another means of transfer consists of patenting and the sale of licences. The significance of these activities is likely to grow following ratification of the new Danish Act on inventions at public research institutions. The Act has resulted in the establishment of a number of patent consortia between universities and other research institutions; in part, their purpose is to promote dialogue with potential purchasers and the exchange of experiences between institutions. Risø has been appointed to head the consortium for inventions in the areas of the environment, energy and transportation.

Towards the end of 1999, Risø has begun the revision of its strategy, a condition of the management performance contract with the Ministry of Research and Information Technology to be adopted by the Board by the end of 2000. The process will involve employees as well as representatives of Risø's private and public sector clients, who will sit on the panels that advise the Board and Management on the further development of Risø's key competencies and on the selection of long-term research goals in the areas of industrial technology, energy technology, biotechnology, nuclear safety and large-scale research facilities.

Joint ventures with our customers will take a prominent place in the revised strategy, particularly because of the value of collaboration as a source of inspiration for strategic research and as an indicator of the societal and industrial relevance of Risø's research.

At the end of 1999, Ulrik V. Lassen retired as chairman of Risø's Board after six years in the position. The Board and Management would like to thank Ulrik V. Lassen for his visionary efforts in positioning Risø in the Danish research system.

There is also reason to thank Risø's employees for their loyal and capable efforts to fulfil the goals we have set, independently or in conjunction with our collaboration partners, and for the research results that have been achieved in the course of the year. These open up new outlooks and new perspectives for technological development that can mitigate impact on the environment and advance the competitiveness of Danish industry. And that is the essence of Risø's mission.

Jørgen Mads Clausen
Chairman of the Board

Jørgen Kjems
Managing Director

New knowledge

Risø's main purpose is research into new technology that encourages innovation and at the same time reduces impact on the environment in the areas of industry, energy and agriculture. This goal has been pursued in 1999, while at the same time we are working on maintaining Risø's role as an international knowledge centre capable of acquiring new knowledge on a global level and producing innovation in Danish contexts. In this chapter, we give a number of examples of new results in 1999.

The world of materials on the nanometer scale

With nanotechnology, it will be possible to manufacture eco-friendly, inexpensive structures, apparatus and "smart" products based on complete control of architecture and processes on the atomic or molecular scale. Risø contributes to accumulating the necessary knowledge.

Plastic copies of the smallest building blocks of the body

During 1999, Risø researchers have demonstrated that it is possible to injection-mould copies of human connective tissue in inexpensive plastic materials such as polypropylene. This involves mimicking structures with height variations on the nanometer scale. Preliminary cell cultivation experiments in conjunction with the Fraunhofer Institute for Biomaterials indicate that the cells recognise the injection-moulded collagen as if they were the body's own tissue. The collagen acts as a scaffold for the cells of the body to create permanent connective tissue. The collagen bundles may also serve as a means of communication between cells, telling them that they are in the correct environment and that they should therefore perform their normal tasks. There is considerable interest in being able to recreate this recognisable environment outside the body. Cultivation of cells is already of major significance in the diagnosis of diseases and, in the longer term, for replacing damaged body tissue. Collagen can be extracted from human tissue, but the process is expensive, complicated and of variable quality. Alternatively, it is possible to copy the contours of the collagen bundles in plastic and then recreate the chemical properties of the collagen on the surface of the plastic.

Natural principle behind new type of sensor

A new type of sensor has been developed for revealing small quantities of different substances in the blood. The sensor is capable of distinguishing between closely related substances. The sensor mimics a natural principle: biological receptors often have a degree of concavity that is complementary to the compounds – e.g. indicator substances, hormones, etc. – with which they are capable of reacting. In the same way, a chemist can produce artificial receptors whose shape matches the shape of the molecules to be measured. Risø has used these principles to produce a sensor for the alkaloid ephedrine, which belongs to a group of substances that have valuable medicinal properties, a group which, however, also includes euphoric substances such as "ecstasy". The receptor is based on a so-called calixaren, a cup-shaped molecule.

Exploring the inside of materials

An important aspect of technological development in the area of materials will take place on the nanometer scale. For this reason, Risø needs to have techniques at its disposal that will allow scientists to study

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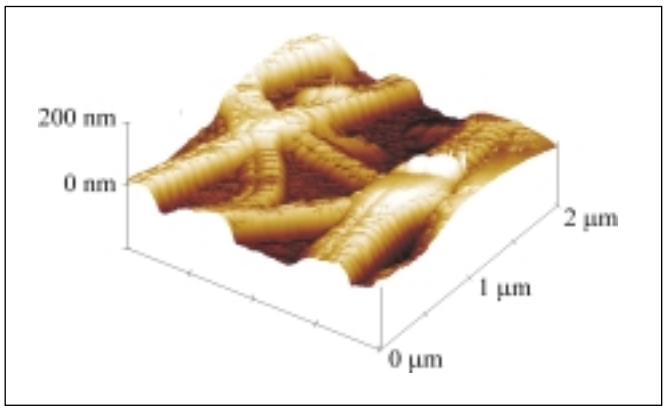
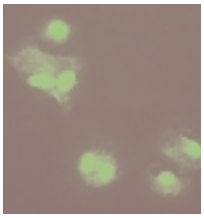
Ph.D. student Nikolaj Gadegaard is working on developing the substrata of the future in the form of plastic copies for the cultivation of artificial tissue, for example for skin grafting.



The researchers might able be to get new tissue to grow on the plastic copies (pictured top right).



The picture at bottom right shows cells recognising connective tissue and growing on it.

BOYE KOCH

This molecule is capable of revealing small quantities of the alkaloid ephedrine in the blood. Ephedrine belongs to a group of substances that have valuable medicinal properties, a group which, however, also includes euphoric substances such as “ecstasy”. Senior research fellow Mikkel Jørgensen has developed the molecule.

materials on the nanometer scale, e.g. X-ray scattering, neutron scattering, Atomic Force Microscopy and TOF-SIMS.

Simulation of neutron scattering experiments

In order to rationalise development of new neutron instruments, Risø has, with EU support, developed the McStas software. Version 1.2 was released in January 2000. The program is capable of simulating the results of changes in the design of neutron scattering equipment, allowing new ideas to be tested prior to construction. McStas is used to optimise neutron instruments at Risø and is a factor in maintaining the position of DR3 as an international large-scale facility. The software is also widely used in the international academic world. Neutrons are used, for example, to study high-temperature superconductors, the structure of enzymes and mechanical stress in motors. Neutrons penetrate deeply into the substances and provide detailed information that cannot be obtained by other means. This technique requires major investment in experimental equipment. The new spallation neutron source, currently being constructed in the USA, will be the most powerful neutron scattering device in the world, with a budget of USD 1,400 million. Thus it is well worth optimising the design and use of existing and future facilities, as is being done at Risø’s research reactor, DR3.

3D X-ray images of the interior of materials

Using X-ray scattering, it is possible to study the inside of materials in 3D. A new X-ray diffractometer developed by Risø was put into service at the ESRF synchrotron facility in Grenoble during 1999. The diffractometer is the first of its kind anywhere in the world to allow 3D structural phenomena to be studied "live" at high resolution. Risø was responsible for developing the equipment, which is used by Risø scientists and by scientists from other countries in Europe. The diffractometer is a good example of Risø’s contribution to the needs of the international academic world. Considerable international collaboration has gone into the development of new software for the equipment.

New technology with non-linear phenomena

An everyday illustration of non-linear phenomena can be seen in the special offer strategy of supermarkets: one apple costs DKK 3. Ten apples cost DKK 25, not DKK 30. There is a non-linear link between the price and the quantity. Non-linear phenomena play a crucial part in understanding all complex systems and are therefore included in several areas of Risø’s research.

BOYE KOCH

New neutron sources are multi-million pound investments. Thus it is well worth optimising existing and future facilities. The computer program McStas is used for calculating the correct design of components for neutron scattering devices, such as the analyser mount, shown here by computer scientist Kristian Nielsen.

Non-linear phenomena behind new optical measuring methods

During 1999, work was carried out with several types of non-linearity in organic and inorganic non-linear materials alike. In optics, non-linear dynamics is used to enable light to be controlled by light. A transmitted field of light affects the mate-

MICHAEL FISCHER

Ph.D. student Sune Lomholt is working on numerical studies of the movement of particles in microflows with a view to designing micro-structures for separating particles and cells in liquids.

rial in the form of a change in the refractive index, for example. This change in the refractive index in turn affects the light field by changing its amplitude or phase. The result of this process can be expressed by the formation of a number of spatial patterns. Further work on these spatial patterns will help, for example, in the development of the next generation of optical measuring methods. Similar spatial structures, in the form of vortices, are formed in rotating fluids and magnetised plasma. These structures control the dynamics of the flow, its mixing and transport properties of, e.g., impurities. During 1999, the formation of vortices, their interaction and their mixing and transport properties have been studied both numerically and experimentally in rotating liquids. This programme area is partly financed as a framework programme of SNF.

New directions in biotechnology

The focus of Risø's plans in the area of biotechnology in 1999 has included quality crops with low-input methods as well as biotechnological research from gene to function.

Proteome analysis

During 1999, Risø has established the basic requirements for proteome analysis, an important element of the "from-gene-to-function" analysis, whereby the proteins expressed in the cell are mapped. Proteome analysis is used in the study of nitrogen symbiosis between plants and micro-organisms. All plants need nitrogen and their metabolism requires nitrogen in the form of ammonium, for example, because they cannot directly utilise ambient nitrogen. Only certain bacteria and blue-green algae master this art, the so-called nitrogen-fixers. The bacteria can live in symbiosis with plants, supplying them with nitrogen. Symbiotic nitrogen fixing is important to agriculture because it saves artificial fertilising. Symbiosis between plants and micro-organisms requires the formation of so-called symbiosomes, cavities housing the bacteria. Symbiosomes are being studied using proteome analysis. From analysing proteins, it is possible to work backwards to identify the gene that was responsible for producing the protein. Thus, this method supplements studies of genes and their function. These methods combine to make a powerful tool in giving a new and improved insight into any biological system. The basic requirements for proteome analysis are now set up at Risø.

Peroxidases – the active defence of plants

A significant result has been achieved in mapping the natural defences of plants. This could reduce the use of pesticides. Just as humans have an immune system, so plants have an active defence. The plant defence arsenal includes peroxidases, proteins that are activated when the plant is attacked by diseases such as barley mildew. Plants contain as many as a hundred genes encoding different peroxidases. The genes are expressed at different stages of the plant's life, which shows that they are necessary to the plant's metabolism. Other peroxidase genes are only expressed for example to counter stress in the plant when it is exposed to disease attack or ambient ozon pollution. Thus, two barley peroxidases, Prx7 and Prx8, are only expressed when the barley mildew fungus attacks and they are therefore easy to differentiate from the more than ten peroxidases normally found in a green barley leaf. These two peroxidases have been thoroughly characterised and the gene encoding the peroxidase Prx8 is propelled into green barley leaves using a particle gun. When these barley leaves are subsequently exposed to infection by the barley mildew fungus, the fungal attack fails far more often than usual. Thus, the gene encoding Prx8 strengthens the defences of the barley plant. The same gene is used to produce transgenic plants and experiments show that these are

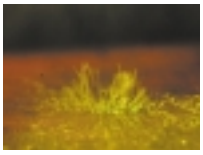
BOYE KOCH

Bacteria are capable of supplying vital nitrogen to plants. This symbiotic nitrogen fixing avoids the use of artificial fertiliser in agriculture and horticulture. Risø is using techniques such as proteome analysis, a new tool in molecular biology, to study the mechanisms. From right to left: senior research fellow Gerhard Saalbach, Ph.D. student Pinar Erik and laboratory technician Ina Hansen.

MICHAEL FISCHER

Ph.D. student Morten N. Grell is working on identifying and characterising new genes of the barley powdery mildew fungus involved in the parasitic symbiosis with the host plant.

RISØ NATIONAL LABORATORY



Like humans, plants, too, have an active defence mechanism against disease. The plant defence arsenal includes peroxidases, which are being studied at Risø. Pictured here under the microscope is barley mildew attacking a plant.

MICHAEL FISCHER

Ph.D. student Lars Frøsig is studying the chemistry of combustion for future alternative and eco-friendly fuels.

incapable of reproducing. Thus, Prx8 intervenes in the essential metabolic processes when it is expressed in the wrong tissue or at the wrong stage of development. Corresponding results have recently been published with a closely related peroxidase in wheat and, taken together, the results represent the first in vivo demonstration of a specialised function of a peroxidase.

Clean, efficient energy for the new millennium

Energy, environment and development planning from global, regional and national perspectives have featured alongside cleaner energy technologies as an important area of activity for Risø during 1999. The objectives of the Danish sub-strategy on environmental and energy research – safe and eco-friendly energy supply – have been incorporated into the planning of research efforts in this area.

IPCC's third assessment report

Risø is involved in the preparation of IPCC's third assessment report (TAR) which began in 1999. TAR involves three working groups whose members are selected based on national nomination and international assessment. Denmark has had three experts selected, where two come from the UNEP Centre, and both are lead authors in working group III. Two of the UNEP Centre's foreign employees have also been selected as lead authors. In addition to the third assessment, IPCC is preparing three special reports on selected topics. The UNEP Centre has been asked to contribute to two of these: emissions scenarios and technology transfer. The UNEP Centre co-hosted an IPCC scenarios workshop in June 1999 jointly with the Danish Energy Agency.

Electric and hydrogen vehicles can contribute to a cleaner urban environment

Recent results show that urban pollution could be significantly reduced if major efforts were invested in promoting cars powered by electricity or using hydrogen as fuel, hybrid versions combining traditional fuels and electricity in vehicles may be the immediate solution. Electric cars can be a way of reducing CO_2 emissions from the transport sector, even given the current pattern of fuel consumption in electricity production. In addition, electric cars if recharged at times when there is surplus supply could improve overall efficiency over power supply. In this way, they would increase the flexibility (capacity for regulation) of the electricity system. This could in turn provide better conditions for integrating variable electrical production, for example from wind power and solar cells. A project examining these aspects has been carried out as a joint venture with DTU, supported by EFP.

Small steps towards sure knowledge of CO_2 and climate changes

At Risø in 1999, a breakthrough was reached in experimental methods to determine the exchange of CO_2 between the sea and the atmosphere. For the first time, it has been possible to obtain the same result from several different experimental methods of determining the exchange of CO_2 over the sea. There is still a great deal of uncertainty with regard to CO_2 and climate. This is the main reason for many of the studies about the exchange of carbon dioxide between the sea and the atmosphere. The surface of the sea absorbs large quantities of the greenhouse gas CO_2 and the oceans constitute a huge CO_2 reservoir. More knowledge of the exchange of CO_2 between the oceans and the atmosphere

is therefore important for understanding future climate changes.

Better weather forecasts and more accurate climate models

Weather forecasts in Denmark and many other European countries are prepared by feeding a series of meteorological observations into computer models such as DMI's HIRLAM. HIRLAM then does its calculations based on an image of the landscape sampled at very low resolution. Details of less than 10 km in each direction are disregarded. Climate models are at an even lower resolution, leading to inaccuracy in the calculations because the exchange of heat, water vapour and the amount of movement between the ground and the atmosphere is an important factor in this type of model. Such exchanges are known to be strongly dependent on vegetation and ground temperature and such factors change many times along a 10 km stretch. The result is an unreliable weather forecast. In a joint venture with DMI and KU, Risø is now seeking to remedy this. The method include satellite images from LANDSAT, in which landscape details are clearly visible right down to approximately 30 m. Using their knowledge of how landscape details affect surface exchange, scientists adjust the model to make its calculations more accurate. Scientists have two ways of checking whether the models are improving. One way is to take a series of meteorological readings in the landscapes that the satellite images come from. The other is to let the model recalculate an "old" weather forecast. This makes it easy to determine whether the "new" weather forecast is better than the "old" one.

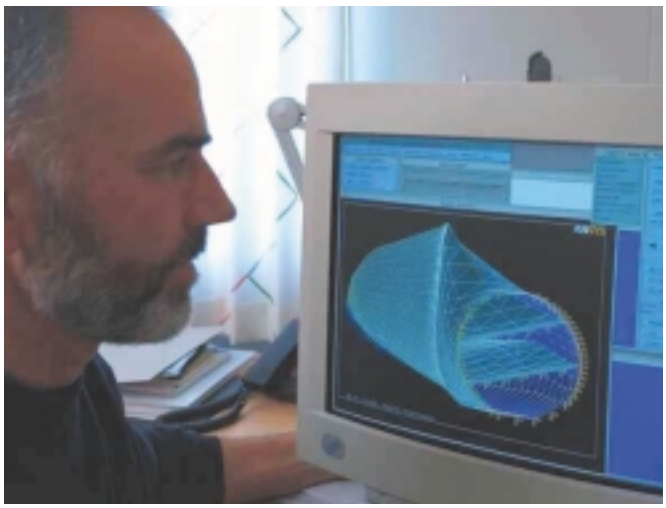
BOYE KOCH

Vibrations damage wind turbines. Pictured here, Andreas Baumgart, Morten H. Hansen and Gunner Larsen discuss modal shapes in a wind turbine blade. Their new knowledge is about to be incorporated into the construction of future wind turbines.

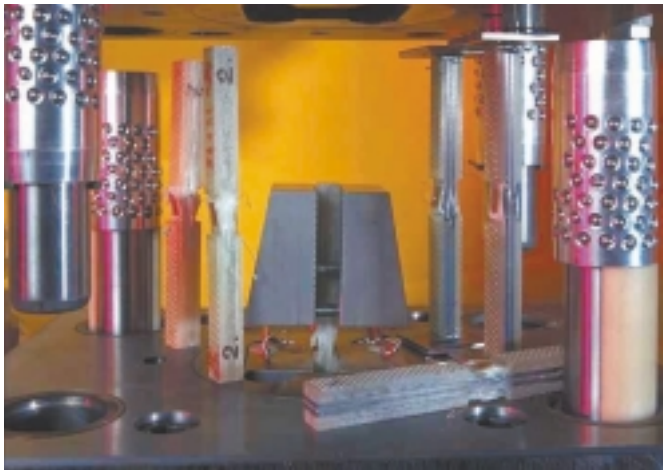
Aerolasticity is the key to wind turbine design

During 1999, new results have been obtained in the research area of aerolasticity, that is, the interaction between aerodynamic forces from air flows and deformation of flexible blades. Aeroelastic factors are of major practical importance in the design of wind turbines. In a co-operation with a manufacturer, Risø has developed and tested a method of experimentally determining the damping of blade vibrations for an operating turbine. This allows improvement in aeroelastic calculation models, leading to more accurate prediction of loads and dynamics. In addition, it can be used for documentation of the characteristics of an existing turbine in connection with certification. In the same context, the aerolastic code HawC has been expanded to allow modelling of mechanical vibration dampers in the turbine nacelle and tower so that optimisation can be carried out by means of aeroelastic calculation. In addition, a method has been developed of experimentally determining the oscillation modes of a wind turbine blade. The oscillation modes measured are compared with existing aerolastic models in which the blade modes shapes are of major significance to the dynamic stability of the entire wind turbine. The methods that have been

BOYE KOCH



The research area of aerolasticity studies the interaction between aerodynamic airflow forces and deformations of flexible wind turbine blades. Risø is studying this using equipment such as the HawC computer program. A number of new methods have resulted and will be adopted by the wind turbine industry. Pictured here, senior research fellow Jørgen Thirstrup Petersen is making calculations using the advanced program.



BOYE KØCH

New, advanced equipment for compression-testing fibre composites is being used inter alia to produce life time models for new, increasingly large wind turbine blades, as well as to study how damage occurs and develops over time. These factors will be particularly crucial for the new large-scale wind turbines positioned at sea with regard to profitability and safety.

developed are now being implemented in industry.

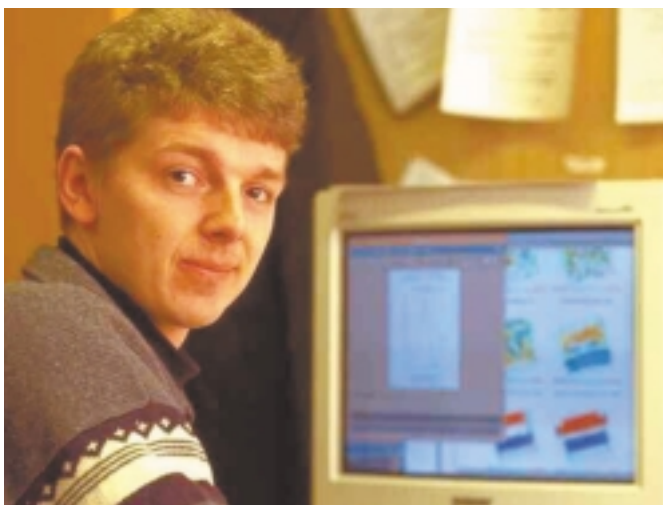
Accurate knowledge of the life of large wind turbines

Larger and larger wind turbines make it necessary to use fibre composites of greater stiffness, for example with carbon fibre instead of glass fibre. At the same time, accurate knowledge of the lifetime of wind turbines is important in determining their profitability. Thus, a preliminary project has been initiated, based on Risø's experience in the manufacture and characterising of mechanical properties of fibre composites, to investigate the damage evolution of new materials and set up life expectancy models for the new materials. Knowledge of the criticality of the damage state and evolution is necessary in order to use non-destructive techniques for determine whether a damage state in a rotor blade is fatal or whether the blade can continue to be used, and for how long, in spite of the damage. These factors will be crucial to the profitability and safety of the new large wind turbines in marine locations.

Progress on the long road to fusion energy

Risø has a collaboration agreement with EURATOM relating to participation in fusion research. Under this agreement, Risø takes experimental, laser-based measurements in order to characterise the turbulence in a large fusion experiment, the Wendelstein 7-AS stellarator in Germany. Concurrently, the problems are being studied through simulation on large super-computers. During 1999, Risø has developed a new method for achieving spatial localisation of turbulence measurements using laser light. In the experiment in Germany, the new method has produced a better understanding of the mechanisms behind plasma turbulence. Risø has participated in the development of a new theory on the effect of turbulent transport in the plasma. The theory has been tested by means of computer simulations and, in 1999, Risø passed an important milestone in the development of these studies when, for the first time, full three-dimensional computer simulations were completed of the temporal evolution of

MICHAEL FISCHER



Ph.D. student Søren Korsholm is working on numerical studies of the properties of turbulence in fusion plasmas. This work may improve the understanding of turbulence and help to pave the way for the use of fusion energy.

Neutrons from Risø's reactor can be used to activate trace elements in various samples, which can then be measured in the gamma laboratory. This highly sensitive measuring method is here used to detect the fraction of an emitted tracer that has deposited on a surface. From left to right: Christian L. Fogh, Kasper G. Andersson and Henrik Prip.

BOYE KOCH

plasma turbulence for realistic geometric models of the magnetic field.

The high-energy neutrons emitted by the fusion reaction damage the materials out of which the fusion reactor is constructed. These problems are being studied at Risø and, in 1999, experimental studies have shown that radiation with 14 MeV neutrons, which are those produced in the plasma, may reduce the ductility and fracture tuffness of the metals, thus reducing the lifetime of the materials. Through theoretical calculations and numerical simulations, these effects are being investigated, which is one step along the road to finding radiation-resistant materials for fusion reactors.

The hidden costs of electricity production

Externalities are generally the term for costs of electricity production not included in direct production costs and hence not reflected in consumer pricing, e.g. damage to the environment. These costs can be established and priced, but they are generally valued differently, depending on which basic criteria are used. During 1999, Risø has analysed some of the most significant causes of differences in valuation and has found a number of explanations that provide a better foundation for the future calculation of externalities.

Nuclear safety

Research in the nuclear safety area aims to secure Risø's status as the Danish knowledge centre broadly covering the areas of nuclear safety, radiation protection, radioecology and the application of nuclear measuring methods. Risø must provide for the needs of the governmental authorities for consultancy in this area as well as participating in international collaboration as defined by treaty in the area of environmental and reactor safety.

Greater accuracy in the reconstruction of radiation doses from nuclear accidents

Risø is continuing to develop and improve a method of retrospective dosimetry based on optically stimulated luminescence where radiation energy stored in materials such as bricks and porcelain is released and measured. During 1999, new equipment has been developed, allowing greater accuracy in retrospective dosimetry in connection with nuclear accidents.

Radioactive pollution of skin, hair and clothing

Airborne radioactive emissions can lead to skin contamination. During 1999, Risø has contributed to studying the significance of deposits of airborne pollution on skin, hair and clothing. This has come about through participation in an EU research project, which has shed light on processes that had previously almost been overlooked. The conclusion is that the problem needs to be taken seriously in relation to airborne radioactive emissions, for example.

Analysis of reactor accident to prevent future accidents

Studying reactor accidents is one means of avoiding future accidents with nuclear power. Under the auspices of Nordic Co-operation on Reactor Safety (NKS), Risø has developed a model for cooling the molten core material that ended up at the bottom of the reactor tank during the accident at Three Mile Island (USA, 1979) without melting through the reactor tank. The model calculations indicate that the formation of cracks and the penetration of water into the solidified core material along the base of the tank may explain how the integrity of the tank was preserved.

Radioactive waste

Radioactive waste must be stored safely until it ceases to represent a potential risk. Risø has demonstrated that barriers made of concrete or other materials containing cement can be used to counter the spread from deposited radioactive waste. Defects in the form of cracks, etc., affect safety. Studies of this have been carried out under an EU contract. Partial results are also relevant to the general use of concrete.

Patents

Consolidation of patenting and licensing activity is central to Risø's basic planning and Risø is making scientists more aware of the opportunities that exist for patenting. The patenting of research results is not an end in itself, but one of the aspects of disseminating research results to industry and protecting Danish industry. Thus, patenting activities are an integral part of Risø's overall strategy and general business policy.

MICHAEL FISCHER

Ph.D. student Guggi Kofod is working on developing materials for use as artificial muscles, for example in robots. Risø's work on artificial muscles has already resulted in patent applications (see table, this page).

Patents in 1999

Ten patent applications were made during 1999.

Title/application	*Application number/inventors*
Electrochemical Cell This invention involves a method of manufacturing high capacity, flexible fuel cells.	Danish patent application no. PA 1999 006623 Carsten Bagger, Søren Primdahl, Mette Juhl Jørgensen
A transformed obligate plant symbiont A mildew isolant for use in the development and testing of a new generation of eco-friendly pesticides. (Targeted pesticides.)	Danish patent application no. PA 1999 01011 Solveig Krogh Christiansen, Lisbeth Gath Jensen and Henriette Giese
Method for determining that a product has been organically produced A control analysis method to determine whether products are organically cultivated.	Danish patent application no. PA 1999 01725 Vagn Gundersen
Conjugated Polymer Actuator This invention makes it possible to combine mechanical strength with electrically controlled volume change in a material, producing a "muscle" effect.	European patent application no. 99.200.250.1 Elisabeth Smela, Peter Sommer Larsen, Ib Johannsen
Nanometer scale modulation This invention relates to a method of providing reliable measuring conditions for use in the electronics industry and for scientific purposes.	Danish patent application no. PA 1999 00918 Robert Feidenhans´l, Paul Howes, Mourits Nielsen, Jan Vedde, Francois Grey
Method of replacing cartilage	Danish patent application no. PA 1999-01-811 Klaus Bechgaard and Jes Bruun Lauritzen
A non-invasive method for the measurement of body fluid analytes This invention relates to a method of non-invasive measurement of glucose in blood	Danish patent application no. PA 1999 01677 P.S. Ramanujam
Biomedical electrode This invention concerns a new design of a biomedical electrode that will have potential applications in electro-surgery, defibrillation and external heart-pacing.	Danish patent application no. PA 1999 01169. Jens-Peter Lynov
Phase Contrast Scrambling An encryption and decryption method for image data, using an optical phase mask.	Danish patent application no. (DK2) PA 1999 00364 Jesper Glückstad
Modification and design of an airfoil This invention is a way of constructing a blade profile, making it possible to control aerodynamic stall characteristics, thus producing stability.	Danish patent application no. PA 1999 01180 Christian Bak and Peter Fuglsang

Publishing activities

Risø's research results in comprehensive publishing activity through articles in international journals, research reports and other publications. This publication activity forms the basis for the dissemination of knowledge and transfer of technology to industry and for the exchange of knowledge with Danish and international research institutions.

A list of all Risø publications in 1999 is published in the report Risø-R-1154. The figures below are based on Risø's total publishing activity, i.e. books, reports and articles in Danish and international journals alike, as well as published and unpublished conference contributions.

Figure 1. Publications and lectures 1999

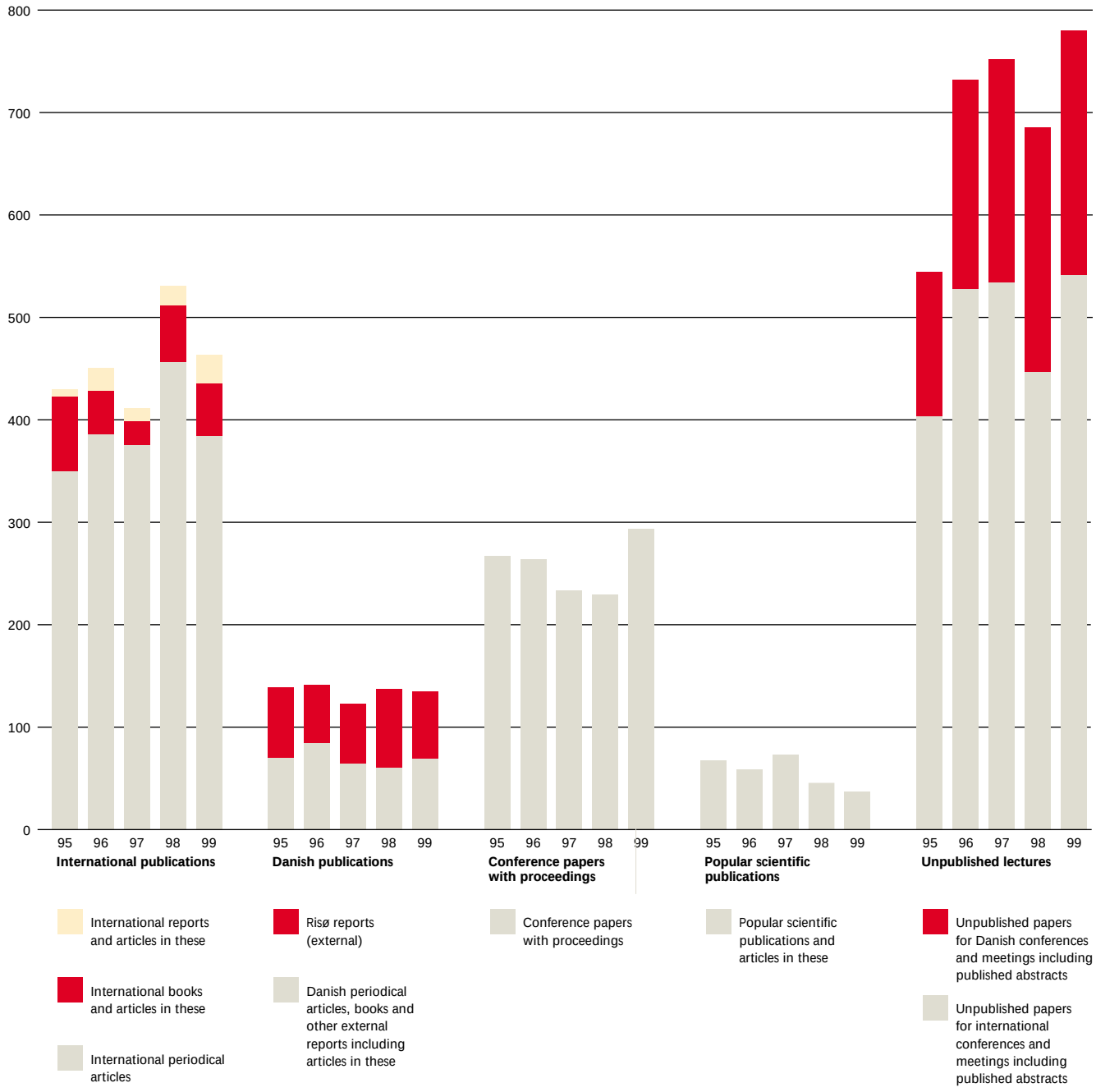
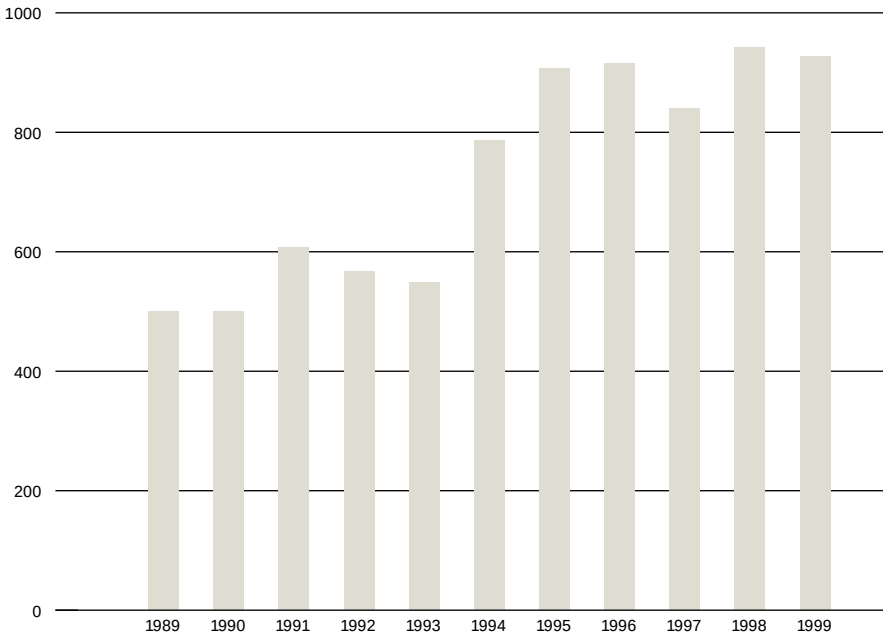


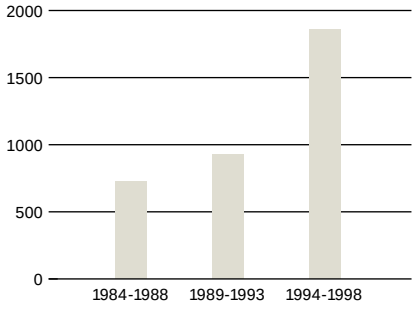
Figure 2. Annual publication activity (totals) 1989-1999



Risø's articles in ISI Source Journals in the period 1984-1998

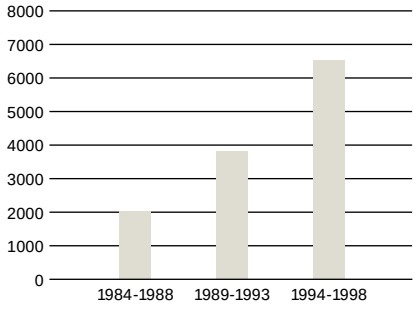
The Institute for Scientific Information (ISI) indexes more than 4000 international journals in the field of the natural and technical sciences, and approx. 3000 journals in the humanities and social sciences (ISI Source Journals). The majority of Risø's international articles are published in ISI Source Journals. For its citation analyses, Risø uses an ISI Institutional Citation Report (ICR), which is a database of references to the articles in ISI's Source Journals, in which Risø is given as the author's address. The database includes information on the number of times the individual articles have been cited. Journal Citation Reports (JCR) are also used. These are an evaluation tool for scientific journals and include information on the Impact Factor of a journal.

Figure 3. Articles in ISI Source Journals



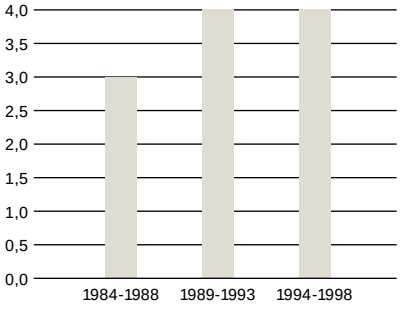
Risø's articles in ISI Source Journals in the period 1984-1998, specified in five-year periods.

Figure 4. Citations



Number of citations from Risø's articles in ISI Source Journals specified for the same five-year periods within which the articles were published.

Figure 5. Citations per article



Average number of citations per Risø article specified for the same five-year periods within which the articles were published.

Figure 6. The 25 institutions with which Risø has jointly published the most articles in the period 1994–1998

The following are the 25 institutions with which Risø has jointly published the most articles in the period 1994–1998, based on ISI's Institutional Citation Report for Risø.

Institutions	Articles
Technical University of Denmark	108
University of Copenhagen	75
Ford Motor Co.	57
Russian Academy of Science	43
University of Oxford	40
KFA Jülich GmbH	39
University of Minnesota	36
Danish National Environ. Research Inst.	31
Aarhus University	28
Weizmann Institute of Science	28
The Royal Veterinary & Agricultural Univ.	26
AT&T Bell Laboratories	25
ETH Zurich	24
Rutherford Appleton Laboratory	23
Inst Max von Laue Paul Langevin	22
University of Hamburg	22
Oak Ridge National Laboratory	20
Hahn Meitner Inst. Kernforsch.	19
Niels Bohr Institute	18
Brookhaven National Laboratory	17
DESY	17
Swedish University of Agri. Science	17
University of Toronto	17
Chalmers University of Technology	16
European Synchroton Radiation Facility	16

Figure 7. The 25 ISI Source Journals in which Risø has published the most articles, within the period 1996–1997.

Shows the 25 ISI journals in which Risø has published the most articles in the year 1996 and 1997 and gives the number of articles in this period. The ISI impact factor is taken from the ISI Journal Citation Reports 1998, where it is obtained by dividing the number of citations in a given year (1998) by the number of articles published in the two preceding years (1996 + 1997). The Citations column indicates how many times Risø's articles from 1996 + 1997 were cited in 1998. Thus, Risø's impact factor is obtained in the same way as ISI's own method of calculation of Journal Impact Factor. Since the ISI calculation does not include articles in the form of editorials, letters, news items and meeting abstracts, these types of articles are not included for Risø articles either.

Journal	No. of articles, 1996-97	Citations in 1998	Risø Impact	ISI Impact
Physical Review B	29	194	6.7	2.8
Physical Review Letter	27	81	3.0	6.0
Physica B	27	38	1.4	0.6
J Nuclear Materials	16	26	1.6	1.2
J Physical Chemistry	16	79	4.9	4.2
Radiation Measurements	14	28	2.0	0.2
Macromolecules	13	24	1.8	3.4
J Physics-Condensed Matter	12	34	2.8	1.6
J Applied Physics	10	13	1.3	1.7
Langmuir	10	34	3.4	2.8
Physical Review E	10	13	1.3	2.1
Europhysics Letters	10	32	3.2	2.2
J Applied Crystallog.	9	11	1.2	1.6
Acta Metallurgica Materialia	9	9	1.0	1.8
Physica C	8	36	4.5	1.1
Materials Sci. Forum A	8	14	1.8	0.7
J Physical Chemistry A	8	12	1.5	2.0
SCI TOTAL E	8	17	2.1	1.2
SCR MATER	8	8	1.0	1.0
ACT CHEM SC	8	17	2.1	1.3
J OPT SOC B	7	5	0.7	1.9
Surface Science	7	8	1.1	2.2
Int J Chem. Kinetics	7	8	1.1	1.2
Plant Soil	7	9	1.3	1.2
Solid State Ionics	7	8	1.1	1.1

Industry and Risø

Risø wishes to step up its market-led activities in order to strengthen the dissemination of knowledge from Risø's long-term research work to leading companies and to Danish society generally. These efforts are also intended to give Risø's employees greater insight into the needs of companies and thus influence the selection of research tasks. At the same time, increased turnover on commercial terms will create greater financial latitude for Risø. During 1999, we have therefore worked to implement a number of commercially-oriented projects to ensure that the development possibilities that Risø creates are exploited in the areas of new materials, energy technology, measuring techniques, understanding of systems and new plant properties.

Advanced measuring techniques produce quality and innovation

New technologies, new processes and products, and analysis of causes of faults and defects in quality require advanced measuring equipment. This comes within Risø's plans to create the technological basis for the development of new measuring techniques.

Electronic nose handles odour genes

Today, sensitive sensors can tell the difference between Scotch whisky and Irish whisky but they are nonetheless not as sensitive as the human nose. On the other hand, the electronic nose does not get tired or lose concentration, so it is better at process control. Risø is involved in a new project to develop sensors for measuring and controlling odour genes from production of insulation materials as well as for the production and monitoring of foodstuffs. The focus is on sensors based on oscillating quartz crystals and semiconductor sensors. The "noses" can also be used in process control as well as in environmental and security surveillance, for example for "sniffing out" bad food, drugs and emissions of foul-smelling and poisonous types of gas from industry and agriculture. The Force Institute, dk-TEKNIK ENERGY & ENVIRONMENT, PBI-Dansensor A/S, Rockwool A/S and KVL are taking part in the project, which is supported by the Danish Agency for Trade and Industry.

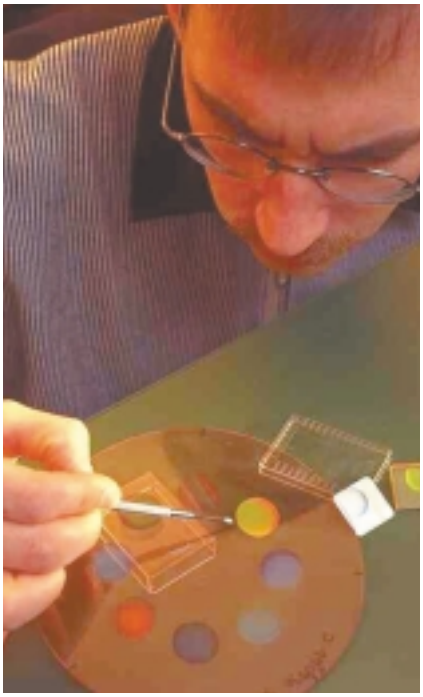
Single-use sensor measures water quality

A new type of water quality sensor has been developed in a joint venture with Vir A/S. Using a diode laser and a moulded plastic diffractive optical element, the sensor is capable of measuring minute concentrations of pollutant substances in drinking water, for example. Since the plastic elements are cheap to manufacture, it is anticipated that they will ultimately be produced as single-use items.

Light shows what is wrong with the patient

Advanced optical measuring methods are opening up new possibilities to medical

BOYE KOCH

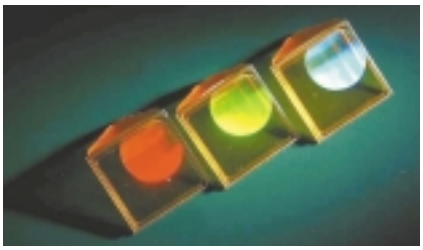


In a joint venture with the company Vir A/S, Risø has developed an inexpensive, single-use sensor for measuring water quality. Researcher Henrik Pedersen is pictured here showing how the sensor is made using a simple injection moulding technique.

BOYE KOCH

An artificial nose never gets tired. This makes it ideal for monitoring odour genes from industrial activity, for example. The "nose" is pictured here, bottom right. Dr.techn. O.Toft Sørensen (left) and research technician Torben Strauss are pictured here examining some of the initial results produced by the "nose".

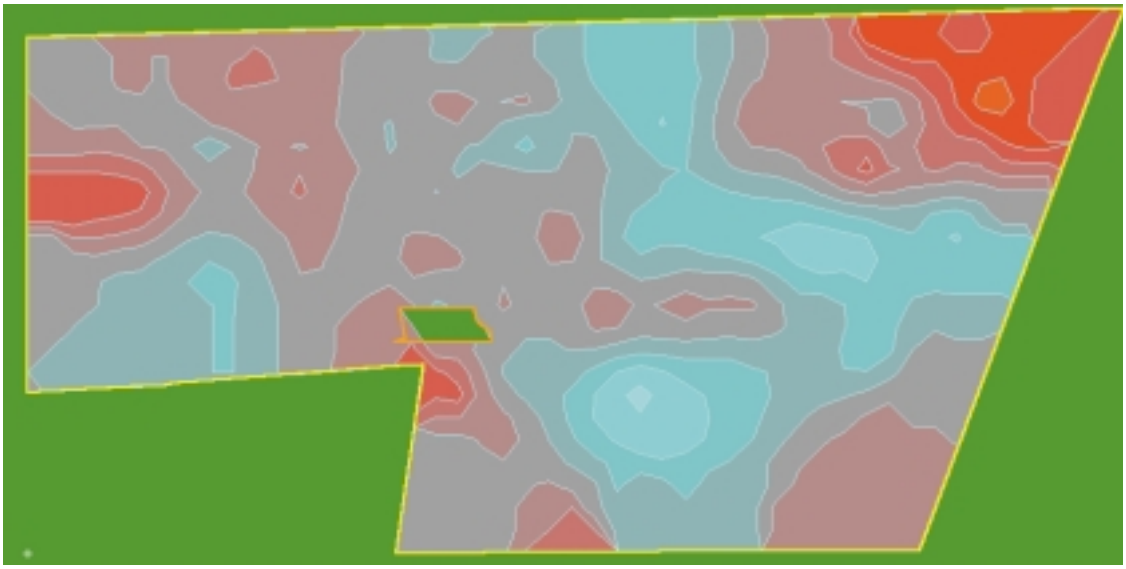
BOYE KOCH



The sensor, developed in a joint venture with Vir A/S, is based on diffractive optics, whereby light is broken down using a lattice pattern, just as the waves of the sea break at the harbour entrance. This makes optical elements compact and inexpensive. Pictured here are three identical diffractive elements arranged at three different angles in relation to the light, causing three different colours to show.

MICHAEL FISCHER

Ph.D. student Peter Lodahl is working on stabilisation and frequency doubling of high-power diode lasers. Laser systems like this will have numerous applications in medicine, sparing patients the hypodermic needle and the scalpel.



The tractor shown at the top is fitted with the Hydro Agri sensor system for varied dosing of nitrogen fertiliser, depending on the individual needs of the plants. The system has been tested at Risø. Among the data gathered are infrared images (centre) of water accessible to the plant. Red represents good and yellow represents low accessibility of water. In addition, analysis of the protein content of crops (bottom), varying from 9.5% (blue) to 12% (red). Final yield card from the tramlines fertilised by the sensor (overleaf) varying from 7 (blue) to 11 (red) tonnes/hectare.

doctors in the diagnosis of various diseases. Thus, pictures can be taken using optical coherence tomography (OCT); within a few years, it is anticipated that this will be important in non-invasive examination of patients. Initially, the system is being developed for the diagnosis of diseases such as eye diseases and skin cancer, for example. Risø has developed a new analytical and theoretical model to describe OCT systems. The principle of OCT involves transmitting light into the eye or into the skin and then using the reflected light to form images, which can help the doctor diagnose the patient's disease. The recently developed model has been verified experimentally on phantoms, i.e. artificial objects with tissue-like properties.

Sensor distribute optimum quantities of fertiliser

Risø has tested a new nitrogen fertiliser sensor for Hydro Agri Denmark. Sensor distribution of fertiliser offers better use of the nutrient for the benefit of the environment and agriculture. In addition, Risø expected that grain quality could be improved. Thus, a joint venture was entered into in 1999 with KVL and DJF,

After the fertiliser has been applied by the sensor the yield map is a valuable tool when the farmer evaluates the decisions made by the sensor in the field. The yield map can be considered on the yearly certificate for the sensor performance. The maps are generated with the software packets Kemira Loris™ (www.KemiraLoris.com)

while The Danish Agricultural Advisory Centre was responsible for nation-wide testing of the sensor system. Experiments have shown that fertiliser application by sensor is justified in modern agriculture. The value of sensor allocation is expected to increase considerably, provided that underlying decision support systems are connected to the sensory devices in future.

New techniques focus sharply on surface properties

A time of flight secondary ion mass spectrometer (CAMECA TOF-SIMS IV), acquired and put into service during 1999, makes it possible to study the chemistry of a surface measuring a mere 100 x 100 nanometers. Such tiny surface structures will increase in technological importance in the next few years. TOF-SIMS supplements atomic force microscopy (AFM), which is capable of detecting the contours of the individual molecules on the outermost layer of a surface, whereas X-ray photoelectron spectroscopy (XPS), which measures the upper five nanometers of a surface, corresponds to some twenty atomic layers. The techniques interact in polymer chemistry, where the analyses are used to tailor materials with the desired properties. The interaction between methods creates the possibility for new breakthroughs in research. Focusing sharply on a small area in TOF-SIMS analysis, it is possible to achieve chemical mapping of the surface that results in an image. For example, during 1999, Risø scientists studied the cross-section of paint for a company, with a view to improving aspects such as colour, stability and adhesion. The method can also be used to study, for example, how pesticides are distributed on the surface or in the cross-section of fruit and vegetables and how medicine is distributed in biological tissue.

Development and sales of devices for dosimetry and dating

The automatic TL/OSL reader is a measuring device unique to Risø. It is used, for example, for measuring radiation doses following nuclear accidents and for determining the age of archaeological finds. The reader has been significantly improved; this has opened up completely new avenues of application. During 1999, the apparatus was supplied commercially to 15 different research laboratories all over the world.

Materials that push the boundaries of technology

Necessary knowledge of new advanced materials is high on the agenda of Risø's basis for planning and materials research encompasses significant contributions from five of Risø's seven departments: Materials Research, Condensed Matter Physics and Chemistry, Plant Biology and Biogeochemistry, Optics and Fluid Dynamics as well as Wind Energy and Atmospheric Processes.

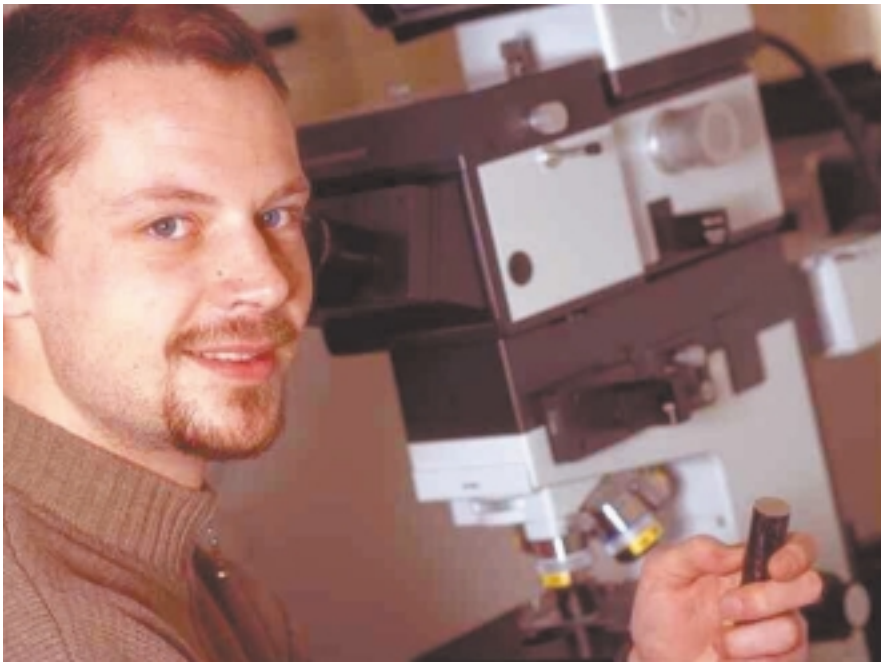
Artificial cartilage may make life easier for arthritis sufferers

Osteoarthritis in the hips and knees is one of the most common diseases in the civilised world. In a joint venture with Hvidovre Hospital, Medico-Chemical Lab. ApS and Copenhagen University Hospital, Risø has been studying alternatives to the insertion of artificial hips. In a literature project, the project group – which has specialist competence in the areas of orthopaedic surgery, polymer chemistry and biology – has reviewed the possibilities of replacing the worn cartilage with an artificial material based on blends of known polymers. A patent application has been submitted for the ideas for the new material. Such a material could replace damaged cartilage in cases where the physical load on the joint is not excessive. The project is supported by the Danish Agency for Trade and Industry.

Plastic moves electronics into everyday goods

Low-cost plastic transistors have many interesting applications, for example as labelling and 'electronic barcodes' on consumer goods. Such transistors are being developed at Risø's laboratories, among other places, through FREQUENT, an EU ESPRIT project in which Risø is participating in joint ventures with groups from the universities of Cambridge, Ulm and Eindhoven, as well as from the development department of Philips in the Netherlands. During 1999, significant progress was made in understanding the

MICHAEL FISCHER



Ph.D. student Christian Højerslev is working on the effect of micro structure on fatigue damage to tool materials (steel/carbide). Knowledge of these mechanisms helps to extend the life of tool materials many times over.

link between the microscopic structure of plastic materials and their semiconductive properties. This type of knowledge could make a vital contribution to improving plastic materials for the transistors.

New fibrous materials on their way into industry

Composites based on thermoplastics are on their way into industry. During 1999, Risø asked 25 Danish companies about their interest in fibre composites. Eighteen companies responded positively and the majority of answers concerned thermoplastic fibre composites. Risø is working on two techniques for manufacturing components from woven fabric of commingled glass fibres and thermoplastic polymer fibres. One method is aimed at limited quantities of larger components - for example, wind turbine blades. The other is suitable for smaller items to be manufactured in larger quantities. The latter process technology has been developed in co-operation with Trevira Neckelmann A/S and Komposit Procesteknik. The advantages of thermoplastic include the fact that it can be recycled. When recycling a thermoplastic composite product, it can be ground into a granule, reheated to the process temperature, and injection moulded into a new product. In addition to the recycling potential and hence environmental advantages, thermoplastics imply also a major benefits to the working environment.

Energy technologies on the way ahead

One of Risø's goals is to contribute to the industrial development of effective, safe and eco-friendly energy plants through the development of materials for applications such as fuel cells, hydrogen tanks and wind turbines. It remains a Risø ambition to be world leading in the area of wind energy.

Fuel cells for domestic use

National and international interest has been focused on SOFC fuel cells again. New combinations of materials have led to a decreased internal resistance, which enables operation at lower temperatures than the originally foreseen 1000°C. The operating temperature is now down to 850°C and further reduction is possible. Therefore, the ceramic interconnect material can be replaced with a far less expensive metallic material. The electrolytes are now very thin and, therefore, with low resistance. At the same time, new electrodes with higher efficiency have been developed. These improvements make it realistic to envisage small fuel cell facilities in the foreseeable future (3-5 years). Such facilities can be adapted to individual homes or industrial plants with central electricity and heating supply because the fuel cells also produce heat in addition to electricity. Over the next two years, Risø will construct a pre-pilot production facility in order to perfect and scale-up the production methods for the new fuel cell type. The project is supported by PSO funding, Haldor Topsøe, Risø and EFP. It is anticipated, that the small fuel cells may reduce CO_2 emissions by 25% compared to electricity produced from traditional generating plants. In future industrial power production facilities of larger scale (multi MW) fuel cell stacks are combined with gas turbines to give a reduction in CO_2 approaching 50%. Three new patents have been applied for during 1999.

Høvsøre well suited to larger turbines

Wind turbine manufacturers have greater difficulty testing large megawatt wind turbines. Permission to erect them inland is difficult to obtain and they are frequently not sited in the most windy locations. Risø has therefore been working to find a good site for testing megawatt

BOYE KOCH

Pictured here are some of the 29 participants in the fuel cell programme, gathered around the encouraging result of the latest development in cells, a large, flexible, strong cell of more than 500 cm^2. Clockwise from top right: senior research fellows F.W. Poulsen, M. Mogensen, S. Primdahl and P.V. Hendriksen, Ph.D. student Lars Mikkelsen, research technician Henrik Paulsen, Ph.D. student Marianne Glerup and senior research fellow Bruno Kindl.

wind turbines before they are sited in the planned large wind turbine parks at sea. Høvsøre in Western Jutland is an excellent site and large-scale preparations have been under way throughout the year to get the new testing station for large wind turbines established.

Basic design for wind turbines at sea

The utility companies, Det Norske Veritas and two consulting engineering firms have collaborated to set up a basic design for future expansion of wind turbine parks at sea. In establishing the basic design, measurements of climatic conditions at sea, for example, are being taken. The finished proposal for a basic design is being submitted to the utility companies in January 2000.

Power electronics in wind turbines

In a joint venture with a wind turbine manufacturer, Risø has studied and demonstrated development opportunities for the application of power electronics in combination with the Danish wind turbine concept of stall regulation through further development and implementation in a 500 kW turbine with variable speed regulation and using the original control strategy. In future, the structure will be used as a research facility for Risø's ongoing development and refinement of the turbine concepts of the future.

New blade design for stall-regulated turbines

A modification to the leading edge of existing stall-regulated wind turbine blades has been designed, ensuring a more stable stall. Thus, it is possible to avoid several different power levels occurring at high winds, as is the case with some wind turbines today. At the same time, the modification makes the blades a little more aerodynamically efficient and ensures that the performance of the blade is less sensitive to dirt on the leading edge.

Wind turbines in weak power grids

A project is being carried out in conjunction with the Research Institute for Danish Electrical Utilities to study the effect of wind power plants on weak grids. The project has consisted of a study of technical power conditions in wind turbine parks and power grids in India. The project has resulted in a number of proposals to improve power quality. The wind turbines in India must to be constructed so as to withstand major variations in frequency on the electricity grid.

Marianne Glerup shows ten years of development of solid oxide fuel cells from the small, brittle cells to today's large cells, bringing renewed optimism to the SOFC programme, which is also constructing a pilot-scale manufacturing plant.

BOYE KOCH

More second opinion studies

Over the last several years, the wind turbine market has experienced strong growth from year to year. This is also noticeable from Risø's so-called "Second opinion" studies. The purpose of such a study is for a bank or some other investor to confirm the validity of production calculations put forward by a wind turbine park developer. This is done in order to secure the financial side of the project. The number of such studies has been increasing for some considerable time, but in 1999, almost twice as many as normal were carried out. A new aspect is that calculations have also been made for marine wind turbine parks.

New, effective tool for positioning wind turbines: WAsP Engineering

WAsP Engineering is a software package for calculating wind profiles, turbulence, extreme winds and other wind parameters relevant to load calculations. All of these parameters vary from place to place in a landscape, e.g. worst storm for 50 years will typically be much more intense at the top of a hill than over flat terrain. The basis for the calculation of the worst storm for 50 years is an extreme wind atlas prepared for Denmark. Atlas values are modified by the surrounding terrain. Wind turbines are also subjected to load from turbulence and the wind profile (i.e. the air flow is not the same over the entire rotor) and the program is capable of calculating these magnitudes. A Windows-based prototype has been developed and will be implemented for selected users in industry early next year.

Storage tanks for hydrogen cars

Risø is working on two possibilities for hydrogen tanks in cars. One makes use of metal hydrides, where the principle is that hydrogen is stored by combining it with triturated metal. The other is light pressure tanks manufactured from fibre reinforced plastic. Both projects are being carried out in co-operation with IRD A/S and DTU. During 1999, materials have been identified for the metal hydride tanks that are capable of functioning with engine coolant water as a means of cooling and heating the hydrogen tank. The materials are being tested in a test tank at DTU, after which a larger tank will be tested by IRD, certified for safety and fitted in a hydrogen car. Light metal pressure tanks wrapped in carbon fibre are being used as the pressure tank. The metal in the tank construction makes them completely leak-proof to hydrogen, but heavy. For this reason, tanks are being developed where the layer of metal is replaced with a plastic or metal-coated plastic layer, which, however, is not as leak-proof to hydrogen. Therefore, types of plastic must be found that are capable of forming an effective barrier to hydrogen. Initial experiments appear very promising and, in an effort to reduce hydrogen losses further, experiments are under way using metal-coated plastic linings.

BOYE KOCH

Hydrogen is an eco-friendly fuel for cars. Storing hydrogen in light and strong fibre reinforced pressure tanks is an ideal solution. The tanks are being developed at Risø. Senior research fellow Aage Lystrup (left) and research technician Claus Mikkelsen are involved in the project.

MICHAEL FISCHER

Ph.D. student Gregor Giebel is working towards providing improved utilisation of wind energy in Europe. Wind energy could easily provide 15% of electrical consumption throughout Europe. Using more advanced techniques, a higher figure could be attained.

Choice of technology and information flow

Risø is engaged in the analysis of opportunities and consequences for industry, society and research arising from the flow of information as well as the choice, development and commercialisation of new technology.

Technological opportunities included in corporate strategic processes

Risø has entered into collaboration with the two organisations - the Confederation of Danish Industries and Central Organisation of Industrial Employees in Denmark - to develop tools and processes to bring future technological opportunities into corporate strategic processes. The long-term goal is to strengthen companies' technology-based competitiveness. The idea is to develop a Technology Foresight process where corporate strategic opportunities are central – technologically, in terms of competence, etc. – as well as to build up directly usable competence among project participants in the project. A preliminary project is being financed by Industriens Uddannelsesfond.

Information flow within companies

Companies face a major difficulty managing the vast quantities of information produced internally by the company and received from outside the organisation. Staff spend a great deal of time gathering, creating and sharing knowledge to be used in-house as well as externally by interested parties. Most tools for searching and information management have been developed to support individual users, which makes it difficult to search for and share knowledge within work groups. Risø is participating in a joint project with the University of Washington, Microsoft Corporation and The Boeing Company (all in Seattle) to develop systems capable of meeting this corporate need. The project is supported by the National Science Foundation.

Biotechnology in its working clothes

Risø is working systematically on the use of biotechnological methods of producing pasture grass with greater nutritional value. Grass has little impact on the environment and is therefore an important item in the sustainable agriculture of the future. However, the nutritional value of pasture grass is insufficient to allow cattle, for example, to do without supplements in the form of grain-based energy feeds.

Less lignin makes grass more digestible

Rye grass is a very important crop in Europe, where it is cultivated mainly as animal feed. In a joint venture with DLF-Trifolium A/S, Risø is now working on making rye grass more digestible to animals. The digestibility and hence the food value of the grass are reduced because of the presence of the substance lignin, found in all plants. Researchers are seeking to exploit molecular biological methods to produce more digestible rye grass, either by reducing the lignin content or by making it more soluble by altering its chemical structure. This can be achieved by influencing the polymerisation process, the process that gives the lignin its characteristics. One way in which the process is controlled is by enzymes called laccases; a special laccase gene has now been cloned. The gene makes it possible to prevent in an organ specific manner the laccase to be formed without, however, affecting the function of the gene in other tissue in the plant. Using this knowledge, the chemical structure of the lignin can be affected in parts of the plants that farm animals should preferably be able to digest.

Grass with controllable stem and flower formation

Through the Bio-technology consortium, in a joint venture with DLF-Trifolium A/S, Risø is working on developing the know-how that will make it possible to control stem and flower formation in grasses. The benefits will be product-related - in the form of increased food value - and environmental, through the prevention of unwanted spread of transgenes to the wild relatives (biological containment). The research programme has now been fully expanded and employs a total of 16 persons. The programme has established a number of sensitive molecular biological techniques for the identification of genes

BOYE KOCH

Ph.D. student Britta Gavnholt has cloned the enzyme laccase from rye grass. This opens up the possibility of producing rye grass with improved nutritional value for livestock.

BOYE KOCH

In a joint research programme, DLF Trifolium A/S and Risø are collaborating on the production of a completely new type of genetically modified grass with greater nutritional value for cattle. This will mean cost savings on high-energy feed. Researcher Klaus Salchert is pictured here working with laboratory assistant Rikke Bonde on PCR – polymerase chain reaction – whereby millions of copies of a gene are produced for study purposes.

MICHAEL FISCHER

Ph.D. student Christian Sig Jensen is involved in the work of the research programme established jointly by DLF Trifolium A/S and Risø. He is isolating DNA from rye grass samples harvested at different times during flowering induction. Genes that have been "activated" during the flowering process are isolated using various molecular biological methods.

that regulate the flowering process in grasses. More than 20 genes have been identified that are known to relate to flowering, as well as a large number of novel genes, which are active during the development of stems and flowers. Thus, more than 100 different ryegrass gene sequences have been collected in an internal database. The first ryegrass plants genetically modified with potential flowering genes are currently being produced at the DLF-Trifolium Research Division in St. Heddinge.

Clean food

Risø's Biogeochemistry programme includes description of trace elements and the occurrence of substances foreign to the environment, exchange and effects in plant production systems and through the human food chain.

Pollution in fish

Since 1996, Risø has been participating in a major project on residue in fish. The project has been co-ordinated under the auspices of the Association of Danish Fish Processing Industries and Exporters, conducted as a joint venture of Biomar A/S, DIFTA, Steins Laboratorium A/S and the Technological Institute. The target group has been the aquaculture industry in the broadest sense, the fisheries industry and purchasers of fish and fish products. Risø has analysed heavy metals in fish and clams. The results have shown inter alia that sensitive multi-element analysis methods are capable of measuring differences between breeding sites.

BOYE KOCH

Chief analyst Lis Vinther Kristensen preparing clams to be analysed for heavy metals. The analysis method is so sensitive that it is possible to determine what part of the country the clams are from.

Using the tool of risk analysis at salmonella

Risø has been studying salmonella infection in pigs in co-operation with Danske Slagterier. The purpose was to clarify whether principles and experiences from the use of risk analysis for process industry can be transferred and adapted to Danish pork production. The risk analysis is based on functional modelling of pig herds and abattoirs. The main emphasis is on the importance of operational and organisational factors in the analysis of salmonella infection and routes for infection in Danish pig herds and pig abattoirs. The long-term perspective is a deeper understanding of the contexts and assessment of relevant risk factors.

Consultancy and service to industry

Risø sells service and development in the form of laboratory testing and consultancy in the seven programme areas in which we have special competence. We have advanced knowledge and equipment at our disposal; these are also used by private companies.

Operational difficulties at incineration plants

Optical measuring methods are very suitable for non-contact measuring in incineration and gasification plants. Risø has developed methods for rapid, accurate gas temperature measurements (300 – 2000°C), typically used for measuring in small and large Danish incineration plants in situations where doubts as to the quality of operational measurement or operational difficulties exist, as well as where detailed processing information is required. Non-contact flow measurements can also be taken.

Meteorological measurements completed at the Great Belt

Risø's measurements for the fixed link over the Great Belt began in 1977. The measurements took the form of climate readings along a 70 m high mast at the eastern point of the island of Sprogø. During 1989 and the following year, enough data were collected to determine that the bridge could be designed with fewer tough requirements than would have appeared necessary by direct use of the Danish code for wind loading – resulting in considerable savings in construction costs for the bridge. Studies have also been carried out into the danger of icing up and options for abating this; as well as the likelihood that turbulent gusts of wind on the bridge deck would represent a traffic hazard. An important task during the actual bridge construction phase was to specify the weather at the construction site so that the builder and contractors could determine when the weather was too bad for continued construction work to proceed. Readings at Sprogø were concluded in September 1999. Operational measurements are now being undertaken from the bridge itself and, as a final task, now on behalf of A/S Sund & Bælt, a comparison is being made between wind velocities measured from the Sprogø mast and wind velocity measured at the current measuring positions along the length of the bridge.

BOYE KOCH

Risø produces radioactive isotopes for companies engaged in checking for leaks. The isotopes are used for tracing leaks in the numerous conduit systems found in all modern buildings and facilities.

Isotopes for tracing leaks

An increasing number of companies are checking for leaks in concealed conduit systems in private homes and large facilities alike. Risø produces radioactive isotopes for them. The National Board of Health requires employees of these companies to have the necessary health physics knowledge prior to the use of radioactive substances. Risø therefore also

BOYE KOCH

In addition to producing and selling isotopes for tracing leaks, Risø also runs courses for employees of the companies involved to ensure that they know how to handle the isotopes responsibly.

offers company employees a course in health physics. During 1999, seven people from leak-tracing companies took part in Risø's course.

Sterilisation of medical equipment
The company LR Plast has leased Risø's particle accelerator for irradiating products and the company carries out sterilisation by radiation for producers of medical equipment, for example Coloplast. Risø provides consulting support and control measurement. Risø's measuring certificates are accepted by the health governmental authorities as documentation of adequate sterilisation.

Diagnosis of rare diseases
On behalf of the J.F. Kennedy Institute, Risø measures copper in bio-samples for the diagnosis of rare diseases. Risø is one of the few laboratories in the world that measures copper in samples of foetal membrane. The results of the analysis are used in the diagnosis of Menke's disease (a hereditary brain degeneration disorder). Similarly copper in liver samples is used in the diagnosis of Wilson's disease, a genetic defect that leads to the accumulation of copper in the liver.

Radioactive waste
The Swedish nuclear power plant Oskarshamn is planning to expand its store of low-level radioactive waste. As part of a description of the environmental impact, Risø has assessed radiation doses to the local population and found that doses are insignificant in terms of both normal and abnormal incidents.

Licences

It is Risø's goal to strengthen licensing activities and to market research-based knowledge more intensively. Rights to results and know-how (Intellectual Property Rights, IPR) are being established and exploited in conjunction with collaboration partners.

Overview of agreements on rights to inventions for which patents have been applied for.
During 1999, rights to eight patents have been transferred.

Invention/inventor	Rights conferred to
A process for solubilising hemicellulose present in a lignocellulosic material. Patent application no. PA 1998 01133. Risø inventor Anne Belinda Thomsen	Bio Crack Aps
Wind Turbine with oscillation damping means, damping device and a method of damping oscillation in a wind turbine. Patent application no. DK PA 1998 00715. Risø inventor: Flemming Rasmussen	NEG Micon A/S
Improvement of N-Tuple or RAM-based neural network classification system and method. Patent application Nos. DK 162/98 and DK 99/00340. Risø inventors Thomas Martini Jørgensen and Christian Linneberg	Intellix A/S
Method and apparatus for determining the rate of angular rotation of a rotating object. EP 0671 007 (PCT DK 93/00315) US patent 5,636,014. Risø inventor Steen Grüner Hanson	Kanitech International A/S
DK 1498/96 A medicament container for storing a liquid medicament and the use of the container. DK 0128/97. Risø inventor Ib Johannsen	Novo Nordisk A/S
DK 307/98 Medical article with coated surfaces exhibiting low friction and low protein adsorption. Risø inventor Ib Johannsen	Novo Nordisk A/S
DK 314/98 Coating system providing low friction. Risø inventor Ib Johannsen	Novo Nordisk A/S
DK 1998 00731 Medical article with coated surfaces. Risø inventor Ib Johannsen	Novo Nordisk A/S

Education of scientists

Contributing to the education of young scientists is an important task. The number of Ph.D. students at Risø is growing steadily and Risø scientists take part in teaching at the universities. Our goal is to make a contribution in all areas in which Risø's research is relevant to teaching at graduate level. Some examples of these activities are given in this chapter.

Ph.D.s awarded in 1999

Seventeen Ph.D. students have received their Ph.D.s in 1999. Seventy-five Ph.D. students, corresponding to a total of 57.9 man-years, were associated with Risø in 1999. Thirty-nine of these students received a scholarship funded jointly by the Danish Research Academy and Risø; seven were financed by other means.

The number of post doctoral scholarships is 80, corresponding to 57.43 man-years, including 38 international post docs.

Materials Research Department
Peter Halvor Larsen, M.Sc.Tech., Sheffield University, UK
Søren Primdahl, M.E., University of Twente, NL

Condensed Matter Physics and Chemistry Department
Palle H. Rasmussen, M.E., DTU
Thomas Frello, M.Sc., DTU

Optics and Fluid Dynamics Department
Michel R. Schmidt, M.Sc., SDU
Sussie Juul Jensen, M.E., KU

Plant Biology and Biogeochemistry Department
Anders Feilberg, M.Sc., SDU
Stefan Stürup, M.E., DTU
Jesper Platz, M.Sc., SDU

Systems Analysis Department
Steffen Rønsholdt Nielsen, M.A. (social sciences), RUC
Lise Nielsen, M.A. (political science), KU
Ann Britt Miberg, M.A. (psychology), KU

Wind Energy and Atmospheric Physics Department
Jeppe Johansen, M.E., DTU
Jørgen Friis Kjeld, M.Sc., SDU
Josep Moreno, M.Sc., Technical University of Barcelona
Elisabetta Vignati, M.Sc., University of Bologna

Industrial Ph.D.s, 1999
Systems Analysis Department
Christian Rud Pedersen, M.E., 7 Technologies, DTU

On the way to receiving their Ph.D. degrees from Risø:

MICHAEL FISCHER

Robert Horvath is a Ph.D. student in the Optics and Fluid Dynamics Department.

MICHAEL FISCHER

Jesper Rømer Hansen is a Ph.D. student in the Materials Research Department.

MICHAEL FISCHER

Søren Koch is a Ph.D. student in the Materials Research Department.

MICHAEL FISCHER

Matthias Hübner is a visiting scientist working with the characterisation of humus compounds.

MICHAEL FISCHER

Peter Snoer Jensen is a Ph.D. student in the Optics and Fluid Dynamics Department.

MICHAEL FISCHER

Karin Vels Jensen is participating in the development of fuel cells, which are expected to have a great future in micro-district heating and power stations for single-family houses.

Graduate Schools

Graduate school in non-linear science
The graduate school in non-linear science has been established as a joint venture with DTU and NBI. Various industrial companies, including Novo Nordisk, are also participating. The school trains Ph.D. students to utilise the latest knowledge in the area of non-linear dynamics in both industry and research. Currently, some 35 Danish Ph.D. students and 15 post docs at the three participating institutions are connected with the school. Last year, the school had 29 visiting international Ph.D. students. In addition, so far there have been more than 50 visiting professors and scientists, who give lectures and also participate directly in instructing the Ph.D. students.

Knowledge Management Graduate School
A number of Ph.D. projects have been initiated as part of the REMAP project, connected with the European doctoral school of the Copenhagen Business School in the area of Knowledge and Management. The intention is also to develop a Ph.D. course in the area of research management, which will be offered to all Risø's Ph.D. students. In addition, this course will be open to the partners in the project venture and other companies.

MICHAEL FISCHER

Ph.D. student Kristoffer E.N. Jonassen is working in developing a method, to a fast and cheap determination of the binding in soil of compounds from tar pollution.

MICHAEL FISCHER

Benjamin Hinnum is involved in research projects on the development of future eco-friendly, efficient fuel cells.

MICHAEL FISCHER

Poul Møller Hansen is involved in developing optical sensors for use in identifying nitrogen and determining water conditions in winter wheat.

Ph.D. courses

Researcher course in plant-microbe symbioses
Plant-microbe symbioses was the subject of a two-week Nordic Ph.D. course at Risø, subsidised by the Nordic Academy for Advanced Study (NorFA). The course covered a number of the processes underlying molecular communication in plant-microbe symbioses. The course was largely based on laboratory experiments, which provided a thorough introduction to some of the latest biotechnological techniques in the area of research into plant-microbe symbioses. The scientific content of the laboratory experiments was integrated with theoretical discussions and lectures by leading international scientists and Nordic lecturers in this field of research. Fifteen Ph.D. students took the course, all of them studying at Nordic universities, but representing a total of eleven countries from around the globe. The course was hosted by the Centre for Plant-Microbe Symbioses, at Risø.

Course on molecular markers
Molecular markers in plant breeding is the title of a two-week Ph.D. course within The Graduate School for Veterinary and Agricultural Sciences of Denmark offered annually at Risø. This year, nine students took part, from Denmark, Sweden and Finland. The course gives students a basic knowledge of molecular markers and their application in plant genetics and plant breeding, concluding with an oral examination.

Information technology in agriculture
Risø has in 1999 become member of The Danish Informatics Network in the Agricultural Sciences (DINA). The network includes a research school with Risø students participating. Risø is responsible for the plant-biological aspects within the network in relation to the areas of bioinformatics and quantitative genetics.

Specialist education

Course on reactor physics
Last year, a Risø scientist gave a course on reactor physics at DTU for 26 students. An experimental course, on practical reactor physics was given in January at the training reactor, DR1, also for students from DTU.

MICHAEL FISCHER

Janka Zrubcova is an exchange Ph.D. student from the Slovak Academy of Science. Her work at Risø involves characterising the physical properties of polymers.

Risø advises governmental authorities

Risø has the responsibility of being the only knowledge centre in Denmark that can advise the governmental authorities on nuclear matters. However, Risø also supports Danish and international governmental authorities and organisations in many other areas through consultancy, studies and R&D assignments.

Risk and safety

Hazardous goods on the Øresund Fixed Link

Risø has prepared an analysis on behalf of "Farligt Gods arbejdsgruppen under Øresunds-konsortiet" (hazardous goods working party under the Øresund consortium) incorporating a decision model for selecting restrictions for the conveyance of hazardous goods on the Øresund Fixed Link. Participants in the hazardous goods working party include Danish and Swedish governmental authorities, including the Ministry of the Interior's Emergency Management Agency, the Swedish Rescue Services Agency and Tårnby Fire Services. Risø's analysis has resulted in a decision template, assessments of the course of three major accidents on the Øresund Fixed Link and on alternative routes, as well as a ranking of six specified possible restrictions.

Energy

Wind energy in India

In its capacity as consultant to Danida, Risø has implemented Phase 1, with the establishment of a wind energy centre in India. Risø is developing the wind energy centre so that it will be able to certify and take measurements of wind turbines. The establishment of a wind energy centre is considered significant for market development in India.

Joint guidelines for reduction in emissions

During 1999, the UNEP Centre published a new set of guidelines for national analyses of emission reductions, as well as a number of reports presenting the results of several national studies in which the guidelines have been tested and applied. Altogether, there are 20 volumes in the report series; it is one of the results of a major project that the Centre has carried out for UNEP, with funding from the Global Environment Facility (GEF). The guideline reports were formally presented at the meeting in June of the subsidiary bodies under the climate convention, at which occasion the Centre also held a seminar on the results of this work organised by the Convention Secretariat.

Transportation and increase in greenhouse gases

The transport sector is the fastest growing source of emissions of greenhouse gases in the vast majority of countries. In most major urban centres, local environmental impact from transport related emissions represents a direct threat to health, particularly in developing countries.

MICHAEL FISCHER

Ph.D. student Thomas Bove is working on methods for improving the safety of air traffic control in view of the constant increase in air traffic.

During 1999, the UNEP Centre prepared a set of guidelines for the World Bank on the integration of the greenhouse gas concerns in particular into traditional transportation and town planning. The Centre was responsible for preparing the report with input from researchers from the University of Bath and Lawrence Berkeley Laboratory.

Renewable energy in African countries

Risø collaborates with UNEP on activities in the areas of energy and climate change through the UNEP Centre. In the area of energy, work is being undertaken especially on renewable energy technologies (RE). Pilot studies have been initiated in a number of African countries and an African programme has been prepared for to

BERT WIKLUND

Risø and New and Renewable Energy Authority (NREA) in Cairo together operate 21 meteorological stations in Egypt for the Wind Atlas for Egypt. Pictured here is a recently erected 30-MW wind farm near Zafarana, Egypt. This farm is phase one of 60 MW in total being built in co-operation between Denmark and Egypt and it is the first of a number of large wind farms planned in the Gulf of Suez. The wind measurements carried out by Risø and NREA form the basis for this huge investment in wind energy in Egypt. Risø is further acting as consultant regarding the siting, wind farm layout and performance verification of the wind turbines.

MICHAEL FISCHER

Ph.D. student Kim Rose Olsen is working on a project on the participation of the developing countries in international environmental agreements.

support establishment of local production of RE technologies.

Follow-up on Kyoto

In the area of climate change , the UNEP Centre is currently working on analytical questions in relation to the so-called Kyoto mechanisms – International Emissions Trading (IET), Joint Implementation (JI) and Clean Development Mechanism (CDM). CDM is the only mechanism involving developing countries. Two regional African workshops have been organised for UNEP and four national pilot studies have been started with a view to assessing the need to increase capacity so that the countries will be able to implement future CDM projects.

Danish contribution to the climate change convention

The reports of the Danish Energy Agency and the Danish Environmental Protection Agency to the Climate Convention and the ECE protocol have received contributions from Risø in the areas of assessment and the forecasting of GHG emissions. Another activity has been the development of environment-related satellite models for ADAM, a model that is used for official forecasts of economic activity in Denmark. The satellite models that have been developed are available to the public and, in 1999, EMMA, which describes energy consumption, energy conversion and related emissions, as well as a simple scenario model of waste generating, was used for environmental assessment of the Year 2000 Budget.

Consequences of deregulated electricity markets

The deregulation of the electricity and gas markets has necessitated the construction of new markets, electricity power pools and financial markets. Risø has carried out several analyses of the transition from monopolistic to deregulated markets. During 1999, the analyses have focused on competition, obstacles to energy environment policies and how to secure ongoing expansion with renewable energy plants in a deregulated energy market. In this connection, analysis includes environment-related markets such as, for example, a market for green certificates.

Biotechnology

Assessment of consequences of genetically modified plants

Risø is collaborating with a number of Danish governmental authorities in research into the possible consequences of cultivating genetically modified plants. This is being done in joint projects financed by the authorities and through the participation of the authorities in steering groups for Risø's programme research, including SMP. The projects have included, for example, a report on spontaneous cross-breeding between the 50 most important Danish agricultural plants and related wild species, as well as experimental analysis of the capability of the field mustard weed (Brassica rapa) to reproduce with transgenes transferred from oilseed rape (Brassica napus) in cross-breeding. Currently, studies are being carried out as to whether genetically modified grasses will spread via other parts of the plant. In endeavouring to prevent the formation of flowers in several different types of genetically modified crops, so that the inserted transgenes will not spread by pollen or seeds, it is important to know whether the plants will thereby gain more resources to spread by means of runners, corms or other reproductive organs. Risø is also contributing specialist opinions in connection with applications for marketing within the EU and the growing of genetically modified crops.

PAH in fruit and vegetables from tar-polluted soil

On behalf of the Danish Environmental Protection Agency, Copenhagen Municipality and Northern Jutland County, and with VKI as project manager, Risø is participating in a project to identify a number of PAH compounds in fruit and vegetables cultivated in tar-polluted soil. For health reasons, the food governmental authorities advise against eating fruit and vegetables cultivated in soil polluted by PAH compounds. Risø is developing methods to clarify the bio-availability of

BOYE KOCH

BOYE KOCH

Bumblebees manage to pollinate oilseed rape and the field mustard weed in one of Risø's experiments to clarify the spread of genes from genetically modified oilseed rape. Left: Senior research fellow Rikke Bagger Jørgensen and Ph.D. student Marina Johannessen watch the experiment. Right: Marina Johannessen and laboratory assistant Bente Andersen produce planting stock for use in analysing the spread of genes.

organic substances in the soil and we are preparing actual risk assessments. Risø is unique in having expertise in the analysis of PAH compounds in plants.

Nuclear safety

Isotopes used in mapping pollution
Information on isotope ratios in elements may lead directly to the source of lead pollution of the environment or show how people absorb nutrients from food. Risø's trace element detection device, an HR-ICPMS mass spectrometer, has been used to determine isotope ratios of calcium, zinc and iron in tests on humans, primarily using faeces and urine, for the purpose of identifying the absorption of the substances from food by the intestine. This work has been carried out in a joint venture with the Research Department of Human Nutrition, KVL.

RODOS - a new decision support tool for nuclear accident preparedness
In the nuclear area, an important new preparedness system was delivered in 1999. The Chernobyl accident in 1986 kick-started development of the RODOS warning and preparedness support system (Real-time On-line DecisiOn Support). The system provides decision support to preparedness and Emergency management organisations in Europe in the event of future major nuclear accidents. The system combines data on current weather conditions and radioactive pollution with models capable of calculating the spread of pollution locally and across national boundaries. Risø has participated in this EU-sponsored project from the outset. The project, a joint venture of 40 institutions in 20 countries, was completed in 1999. Through the Fourth Framework Programme of the EU, Risø was responsible for the integration of a comprehensive atmospheric spreading module, MET-RODOS, in RODOS. In MET-RODOS, real-time atmospheric wind and dispersion models, including the Risø RIMPUFF model, are integrated with current on-line meteorological weather forecast data in a UNIX-based system, allowing the module to supply realistic wind fields and atmospheric dispersion prognoses. Activities will now continue in areas including transferring and adapting the dispersion modules from MET-RODOS to the PC-based decision support system of the Danish Emergency Management Agency, ARGOS-NT.

Radon in Danish houses
Risø supports the National Institute of Radiation Hygiene in the mapping of radon levels in Danish homes. Readings have been taken in more than 3,000 houses, evenly distributed throughout the country. The project will be concluded at the beginning of the year 2000.

Thule
In 1999, Risø concluded its analysis of samples gathered at the latest studies in Thule in 1997. The results show that plutonium remains accessible in the sediment, since the upper layers of sediment are constantly being agitated by the abundant fauna on the seabed. Transfers of plutonium to seabed fauna is very slight, however: the plutonium concentration in the groups of fauna studied are 10–100 times lower than in the sediment.

Plutonium 240/239 isotope ratios in relatively strong samples from Thule have been analysed using Risø's trace element detection device, an HR-ICPMS mass spectrometer. This is also used in analyses of the radioactive isotope neptunium 237 in seawater from Kattegat. Applications of neptunium 237 include its use as a marker in mapping ocean currents.

Cleaning up after chemical and nuclear accidents
During 1999, a method was developed of choosing the best strategy for cleansing areas that have been radioactively or chemically polluted. The work was carried out as an EU project in conjunction with four other research institutions. Exposure of the population, the physio-chemical form of the pollution, the effectiveness of the method of cleansing and financial and social factors are taken into account in optimisation.

BOYE KOCH

Fruit and vegetables grown in soil polluted by tar may contain hazardous PAH-compounds. Risø is the only place in Denmark with the capacity to analyse PAH in plants. Pictured here is researcher Gerda Krog Mortensen carrying out this type of analysis.

BOYE KOCH

Analysis of trace elements by mass spectrometry is carried out in a clean room to ensure that the sensitive analysis is not marred by any ambient dust or dirt. This also requires changing clothes before entering the room. Pictured here is laboratory assistant Jette Bruun Nielsen preparing a sample for analysis.

Finances

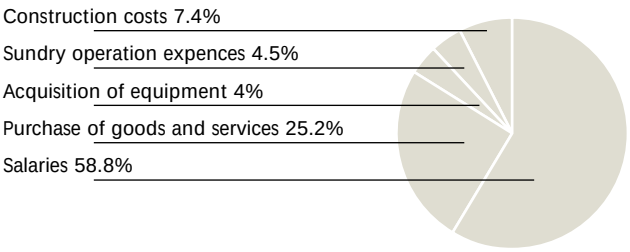
Operating statements for the state institution Risø				
DKK million at current prices (excluding VAT)	1998 accounts	1999 accounts	Budget 2000	Notes
Government appropriations for operating, plant and equipment costs (adjusted net total)	262.8	264.3	267.5	
Contract earnings	235.3	244.9	261.1	
Total Income	**498.1**	**509.2**	**528.6**	
Wages and salaries	283.9	290.5	307.4	
Other operating costs	173.5	180.3	175.9	1
Cost of construction	46.4	38.0	48.2	2
	-	-		
Total expenses	**503.8**	**508.8**	**531.6**	
Result (to be carried forward)	**- 5.7**	**0.3**	**- 2.9**	

1. Of which DKK 8.2 million were plant and equipment expenses in the National Accounts.

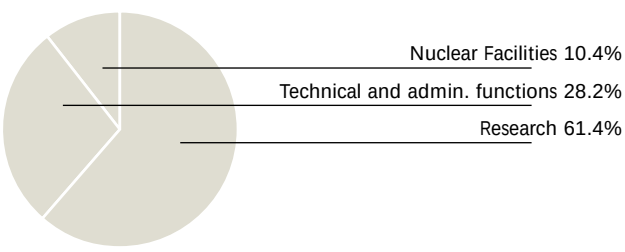
2. In 1999, two loads of spent reactor fuel were dispatched instead of the normal one load. Excluding reactor fuel, the level of other operating costs is unchanged in 1999.

Halden project (statutory)				
Government appropriations	1.6	2.1	2.1	
Subsidy	1.5	1.3	1.6	
Result (not to be carried forward)	**0.1**	**0.8**	**0.5**	

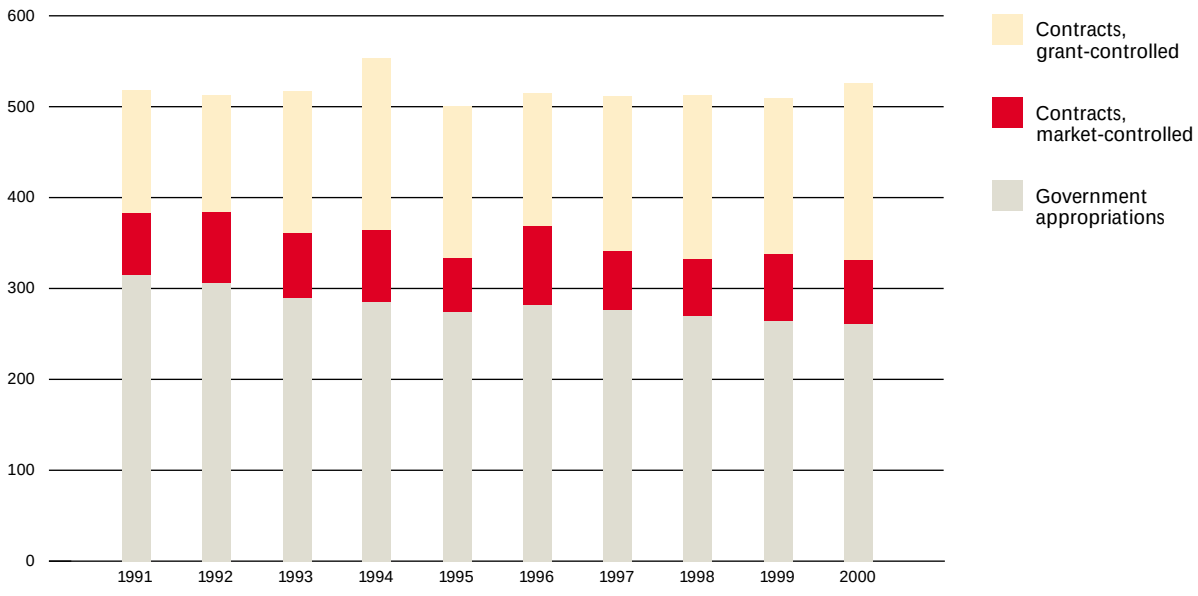
Percentage distribution of expenses 1999



Distribution of expenses by area 1999



Income development (1999 price-level, DKK million)



Balance sheet at the end of December

DKK million at current prices	1998 accounts	1999 accounts	Noter
Assets			
Tangible fixed assets	231.7	227.7	1
Current assets			
- Liquid holdings	2.6	35.1	2
- Accounts receivable	94.5	115.6	3
Total assets	**328.8**	**378,4**	
Liabilities			
State financing of Risø's activities:			
- State financing of plant and equipment	231.7	227.7	
- Accumulated result from operations	14.0	14.3	
- State financing of other assets	53.3	77.6	2
Short-term debt	29.8	58.8	4
Total liabilities	**328.8**	**378.4**	

1. The book value of fixed assets at the end of 1999. The amount is an accumulation of construction, acquisitions and disposals reduced by the value of depreciation. 5% of the accumulated balance is depreciated using the straight-line method according to the Budget Guidelines. In comparison, Risø's property was valued at DKK 385.4 million in the official property valuation in 1999. Machines, fixtures and fittings are usually not included in fixed asset book values.

2. The statement of liquid holdings has been amended in the balance sheet for 1999, since Risø's balance with the state is reported on an account with the National Bank, bearing interest pursuant to the accounting method applied for independent liquidity. As of 31.12.1999, the balance on this account was DKK 30.6 million. As a result of the accounting method applied for independent liquidity, this balance is also included on the balance sheet as part of state financing of other assets.

3. Of which costs met to be invoiced in the following financial year (EU projects, etc.), DKK 38.6 million during 1999 compared to DKK 35.1 million in 1998.

4. The comparatively large fluctuation from 1998 to 1999 is due in particular to an increase in deposits with reference to goods and services to be supplied at a later date, a total of DKK 28.3 million in 1999 compared to DKK 12.0 million in 1998.

Green Account

Risø's Green Account contains information on Risø's compliance with legislation and approvals in the area of safety (external environment, the working environment, health, nuclear safety and radiation protection), on essential consumption of resources, emissions into the environment and effects on staff; a new element, absence due to illness, has been included in 1999.

Risø's Green Account has been a part of Risø's Annual Report since 1996. Its purpose is to state Risø's safety position in relation to society at large. In 1999, this information has been supplemented with Web pages on Environment & Safety, where we publish items of interest concerning safety matters at Risø.

Risø's strategy is that safety work should be preventative, that safety is a natural part of everyday work and that there is a definite link between management responsibility and responsibility for safety. Thus, Risø undertakes annual Working Environment Mapping, where major improvements are incorporated into the planning basis. Safety work in the individual departments is incorporated as a part of the annual assessment of the results of the department. In 1998 and 1999, a Health and Safety report has been prepared for Risø as a whole and for each department.

Risø's emissions into the environment and effects on staff lie at large below the fixed limits or typical values. Some fields are improved compared with 1998 and other are reduced. The level of safety at Risø is good, but in accordance with safety policy, there are ongoing efforts to seek improvement in this area.

Risø's Green Account

Environmental statistics for Risø National Laboratory	Environmental key figures 1998	1999	Risø 1999	Limit or typical values [a]
Injunctions, etc.				
Injunctions from the environmental authorities	0	0		
Petitions from the environmental authorities	0	0		
Injunctions from the Labour Inspection Service	0	0		
Guidance from the Labour Inspection Service	4	1		
Instances of exceeding limit values for sewage	0	0		
Violations of 'Conditions for operating nuclear facilities'	4	5		
Special reports on the nuclear facilities	1	3		
Risks/Health and safety				
Absence due to illness [b] (days lost)	6.0	5.0	7.1	Days lost due to illness [c]
Accidents reported	16	17		
Injuries treated in Risø's emergency room [d]	58	35		
Industrial accidents reported to the Labour Inspection Service	6	9	10 per 1,000 [e]	9 per 1,000 [f]
Industrial accidents reported to the National Board of Industrial Injuries [g]	1	6		
Fire alarms	17	9		
Fires/suspected fires	4	4		
Maximum individual effective dose [h] (mSv)	9.9	7.4	7.4 mSv	20 mSv [i]
Annual collective effective dose [j] (man-mSv)	159.3	169.7		
Consumption				
Water consumption (m3)	69,839	63,822	67 m^3/PE	62 m^3/PE [k]
Power usage (MWh)	11,884	11,613	111 kWh/m^2 [l]	78 kWh/m^2 [m]
Heating (MWh)	12,465	11,138	168 kWh/m^2	176 kWh/m^2 [n]
Natural gas [o] (m^3)	1,733,257	1,750,439		
Coolants [p] (kg)	220	212		
Atmospheric emissions				
^{41}Argon (from DR 3) (GBq)	24,500	16,000		
Tritium (tritiated aqueous vapour from DR 3) (GBq)	3,980	16,000 [q]		
Iodine (GBq)	Negligible	Negligible	0.7 µSv/year [r]	200 µSv/year [s]
^{14}C Carbon dioxide (from the Waste Management Plant) (GBq)	11	4		
Particular ß activity (GBq)	Negligible	Negligible		
Sewage, etc.				
Sewage (m^3)	52,200	55,000	55,000 m^3	182,500 m^3 [t]
Chemical oxygen demand, COD (kg)	1,644	1,716	31.2 mg/l	
Biochemical oxygen demand, BI5 (kg)	131	160	2.9 -	15 mg/l
Suspended state (kg)	277	242	4.4 -	20 -
Total nitrogen (kg)	277	215	3.9 -	6 -
Total phosphorus (kg)	99	121	2.2 -	
pH	8.0	8.0	8.0	6.5-8.5
Sediments (ml/l)	0.1	0.1	0.1 ml/l	0.5 ml/l [u]
Heavy metals [v] (kg)	7.2	3.5		
of which: zinc (kg)	6.2	3.2	58 µg/l	1,000 µg/l
Tritium with distilled active sewage (GBq)	4,200	30,100 [q]	30,100 GBq	36,500 GBq [w]
Tritium in secondary cooling water from DR 3 (GBq)	99	77	3.3 kBq/ml	370 kBq/ml
Unspecified ß-activity in treated sewage [x] (GBq)	0.077	0.055	0.0015 Bq/ml	0.15 Bq/ml
Sewage sludge				
Quantity of sludge (tonnes)	6	11		
Heavy metals [y] (g)	14,000	17,500		
of which: Mercury (g)	29	57	5 mg/kg	0.8 mg/kg [z]
Cadmium (g)	51	57	5 -	0.8 -
Nickel (g)	137	285	25 -	30 -
Lead (g)	371	422	37 -	120 -
Copper (g)	2,240	3,110	273 -	1,000 -
Zinc (g)	5,790	7,830	687 -	4,000 -
Uranium (g)	51	57	5	*2-10* -
Waste				
Waste to be disposed of outside Risø (tonnes)	164	133		
of which: Refuse disposal (tonnes)	79	77		
Mixed waste (tonnes)	80	50		
Chemical waste [aa] (tonnes)	6	6		
Waste for recycling (tonnes)	65	78		
of which: Recycled paper and pulp (tonnes)	19	31		
Waste metal (tonnes)	35	45		
Waste for disposal at Risø (tonnes)	3	9		
Low-activity waste from Risø [bb] (tonnes)	5 [cc]	6		
Low-activity waste from elsewhere in Denmark [bb] (tonnes)	3	2		

Notes

a Wherever Risø's endorsements specify limit values, these are noted. In some fields there are no limit values. As a comparison, as far as possible, limit values characteristic of equivalent areas/fields have been given in italics.

b Absence due to illness includes absences for appointments with doctor or dental and for occupational injuries, but excludes the first day off because of a sick child.

c The average number of days lost due to sickness for selected sector research institutions including KVL.

d The number of injuries, as in previous years, is calculated as all injuries treated by Risø's emergency room, i.e. it includes DMU, visitors and external tradesmen in addition to Risø's own employees.

e Per 1,000 man years.

f Per 1,000 employees in research and development in the areas of natural science and technology. For teaching and research as a whole: 10 accidents/1,000 employees. Source: *Reported industrial accidents, annual report 1996: National Institute of Occupational Health report no. 2*.

g The number of cases reported by Risø, i.e. cases reported by other parties (e.g. general practitioners/ hospitals) are not included.

h Maximum individual effective dose: the individual effective dose is defined as the sum of the equivalent doses to each separate organ multiplied by its respective tissue weight factor. The maximum individual effective dose corresponds to the maximum dose to an individual employee.

i Radiation protection: Dose-limitation principles are applied in the area of radiation protection. These state that doses from exposure to radiation at work should be kept as low as reasonably achievable and that doses must not exceed the dose limits set by the government authorities.

j The collective dose to Risø's employees is defined as the sum of the individual doses received by all persons (effective doses). In 1999, readings were taken from 710 employees.

k Roskilde Municipality's sewage plan, 1988.

l DR 3 and RERAF are not included in the electricity consumption figures by area, as this consumption is unique to Risø.

m Average electricity consumption by area for education and research. For offices and industry, electricity consumption is 51 kWh/m^2 (The Danish Energy Agency, 1999).

n Average heating consumption by area for education and research. For offices and industry, heating consumption is 113 kWh/m^2 (The Danish Energy Agency, 1999).

o Most of the natural gas was used to produce heat and electricity for Risø, DMU and the other institutions on Risø's grounds.

p Account of consumption of fully and partially halogenised hydrocarbons used for cooling purposes. In 1999, a total of approx. 10 kg of freon 12, 120 kg of freon 22 and 75 kg of HFC 404a was used.

q Exceptionally large due to a leak in DR 3.

r The doses from tritium, argon and iodine emissions are effective doses received by an imaginary person standing at Risø's perimeter fence in the same place all year round.

s The maximum contribution from companies such as Risø is suggested by various government authorities as being between 100 and 300 μSv/year.

t The limit value is estimated from the amount of sewage discharge permitted per 24 hours under dry weather conditions.

u Guidelines for the amount of sediment after standing for two hours.

v The total content of the heavy metals for which Risø analyses its sewage. Analysis is performed for lead, cadmium, copper, zinc and uranium. (Heavy metals: metals with a specific gravity in excess of 5 g/cm^3.)

w The value is 10 times the average value since 1995. Risø has to report to the government authorities if the value is 10 times the average value.

x Unspecified ß- activity: Total activity of unspecified isotopes.

y The total content of heavy metals for which Risø analyses its sludge. Analysis is performed for arsenic, lead, cadmium, chrome, cobalt, copper, mercury, lanthanum, manganese, nickel, praseodymium, zinc, thorium and uranium.

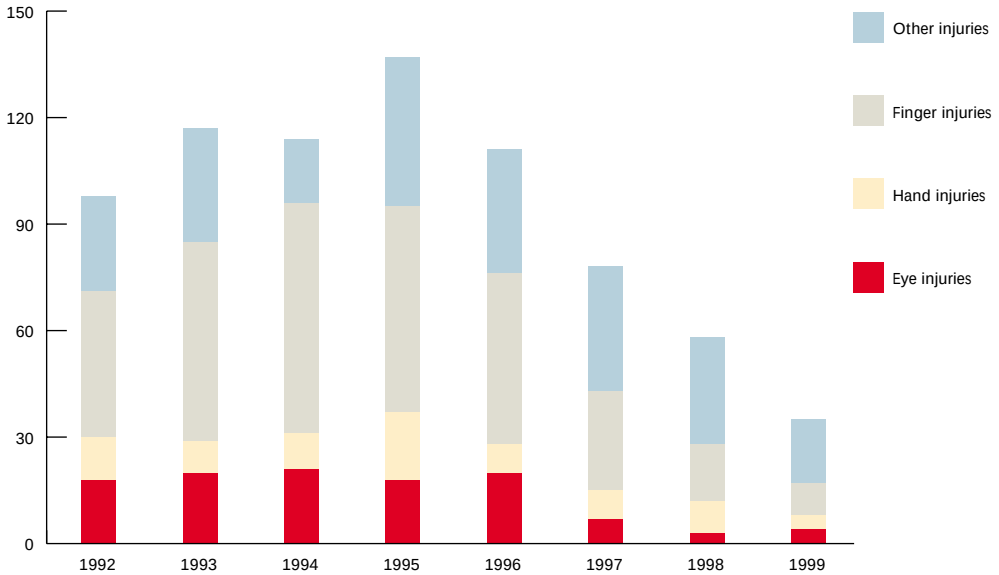
z The limit values for the heavy metal content of sludge apply if the sludge is to be spread on land to be used for agricultural purposes. Risø's sludge is not currently used for this purpose, but is disposed of at Risø's controlled disposal site.

aa In recent years, chemical stocks at Risø have been cleared out. This explains why the quantity of chemicals sent to the municipal disposal facility for chemicals is still higher than normal.

bb Low-activity waste deposited temporarily at Risø derives from Risø's own activities as well as including waste radioactive isotopes from the rest of Denmark which Risø is obliged to receive. Low-activity waste is defined by Risø as radioactive waste for which the dose rate at a distance of 1 m from the surface of the waste container does not exceed 5 mSv/h.

cc The 1998 figure has been changed from that given in Risø's Annual Report 1998 due to a typing error.

Injuries treated at Risøs Occupational Inspection Service.
The number of occupational accidents continues to fall since 1996.



Risø's environmental key figures are specified for 1998 and 1999. Limit values or typical reference values are specified so that Risø's levels can be evaluated in relation to these.

In relation to requirements for the area of nuclear safety, there has been an increase in contravention of the "conditions for operating nuclear facilities" in the years 1998 and 1999. Risø has rectified all this violations These deviations have had no serious consequences for safety. Risø has implemented several initiatives to reverse the trend, for example improving the system of instruction and carrying out a survey of waste flow of radioactive waste. To improve on this further in 2000, Risø will implement a project for continuous improvement of the nuclear safety culture.

The number of injuries treated at Risø's emergency room continues to fall, whereas the same tendency has not been seen in the number of accidents reported to the Labour Inspection Service. In 2000, Risø will be investigating the number of occupational accidents reported. Risø has expanded its preventative efforts in the area of health by collaborating with the Roskilde County prevention council regarding back muscles training for employees.

Following a report on fire safety at DR3, Risø has set in motion a number of fire safety improvements. In addition, Risø will focus on fire prevention by means of an annual review with the assistance of the Danish Institute of Fire Technology.

The number of fire alarms has been falling over the last four years. The four fires/suspected fires in 1999 did not cause major injuries or financial losses.

There is a slight increase in overall radiation compared to 1998, but levels are still low compared to previous years. A drop in maximum individual dose in 1999 is the result of specific action taken.

Risø continuously introduces energy conservation measures, and electricity consumption has therefore remained constant, even though new plants have been brought into use that consume large quantities of energy. Calculated without the plants that consume particularly large amounts of energy, electricity consumption related to the area is still higher than the comparative figure.

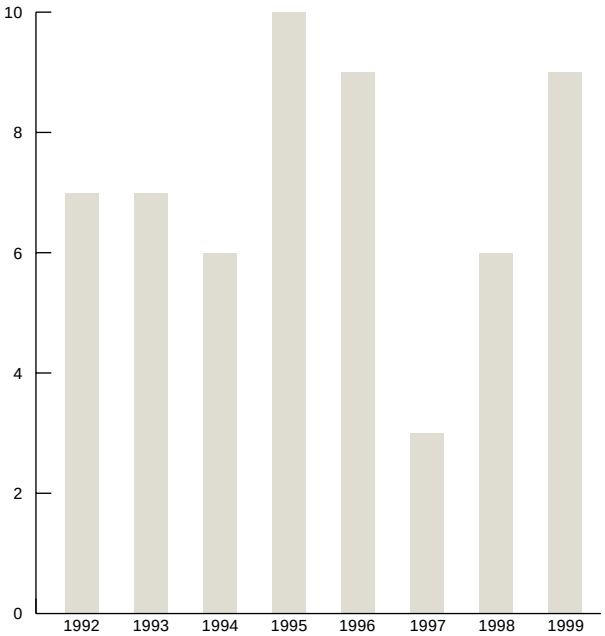
There has been an essential increase in the amount of sewage sludge in 1999. This is due to an increased load in the facility of organic matter and nutrient salt. In addition, following the introduction of biological removal of nitrogen towards the end of 1997, more sludge is being produced than previously. This rebuilding also resulted in a reduction in emissions of soluble organic matter and suspended particles in treated sewage. Concentrations of heavy metals such as mercury and cadmium in Risø's sewage sludge still exceed the permitted levels for sludge to be spread on agricultural land. Risø's sludge is not used for this purpose, but is deposited instead at Risø's controlled disposal site.

In 1999, Risø had an unusually high level of emission of tritium, both as atmospheric emissions and in sewage. The emissions are due to incorrect treatment of water from an ion exchanger and a leak in a drainage pipe at DR 3. The reactor was closed down for repair in connection with this. The increased level of tritium did not lead to fixed emissions levels being exceeded.

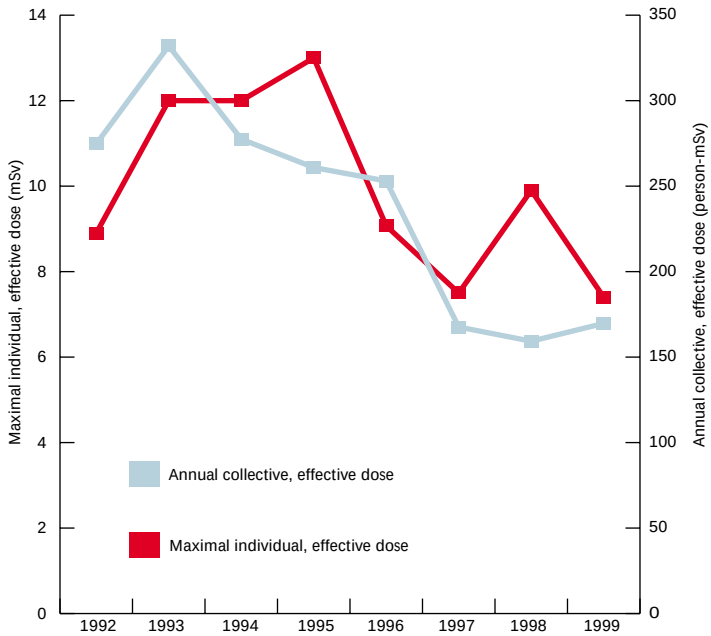
Since the authorities have generally begun to focus on corporate waste management, Risø has chosen to specify types of waste this year.

Viewed overall in 1999, Risø has reached the goals set for green purchases of paper, computers and research instruments. Regarding computers, Risø's goal was that 85% of computers purchased should comply with Risø's environmental specifications. 87% of the computers purchased complied with these environmental requirements.

Industrial accidents
Industrial accidents reported to the Labour Inspection Service.



Individual and collective dose
The maximal individual, effective dose and the annual collective dose for Risø as a total.



Employees and management

Human Resources

Risø's personnel policy consists of a number of themes and tools that are continually being developed and evaluated. During 1999, one of the focal points has been the area of equal opportunities. It is agreed that "mathematical" equal representation of men and women is not an end in itself, but that a balanced combination of men and women produces greater quality in executing tasks and a better climate for co-operation. With this in mind the Central Liaison Committee has adopted a plan of action to promote equal opportunities at Risø.

Teleworking

During 1999, teleworking was discussed in various fora. The conclusion of the discussions was that there is no significant need for teleworking at Risø. Opportunities for working from home as required on an ad hoc basis are widely used, which is why there is limited need for actual agreements on the subject of teleworking. During 1999, there was also more focus on such themes as employee development interviews, Risø's policy on seniority, and the abundant job market.

Performance contracts for managers

During 1999, the entire management group was offered performance contracts. The contracts focus not only on the managers' ability to produce professional results, but also on their abilities in terms of managing research and personnel as well as their ability to create cross-departmental collaboration on an interdisciplinary basis, and their ability to promote Risø.

New salary system for academic staff

Based on a ready-formulated wages policy, negotiations were entered into for the second round for the transition to the new academic salary system. Full responsibility and competence to negotiate salaries is decentralised. In connection with the annual employee development interview it is now possible to discuss salary issues with the immediate superior. Risø has had positive experiences from this.

In-service training

Risø is implementing a targeted in-service training initiative for managers and other employees. Offers of higher education and further training are provided partly through the use of external courses or Universities and partly through Risø's own training programme. The main purpose of Risø's internal training programme is to provide training particularly targeted and developed for Risø's employees.

Course in selling science

During 1999, the "Selling science to industry" project was implemented, with support from the Development and Conversion Foundation. The purpose of the project is to support the objective of the management performance contract with the Ministry of Research to increase Risø's income from Danish industry. Under the management performance contract with the Ministry of Research, there must be intensified marketing of patents as well as development of patenting and licensing work with industry. Against this backdrop, the Personnel Office developed and implemented two courses on patenting and patenting procedures.

IT studies at home

A large number of Risø's staff work with IT every day, but often only for specific purposes within limited areas. The full benefits of the potential of the new technology can only be realised by ensuring that all employees have basic IT competence. It is with this in mind that Risø initiated a project relating to IT studies at home during 1999. Currently, 166 employees are taking their "driving license" to the PC. Of these, 100 employees have been given the use of a PC and printer at home for eighteen months. Thus, the project will be continuing during 2000.

Prizes awarded in 1999:

Senior research fellow Jørgen T. Rheinländer, of the Materials Research Department, has received the Jubilee Prize of Dansk Svejseteknisk Landsforening.

Peter Halvor Larsen, M.Sc., of the Materials Research Department, has received "The Glass Sellers Award in Science and Technology 99" in London. Peter Halvor Larsen has also received Fosters Research Prize, University of Sheffield.

Dorte Juul Jensen, Ph.D., of the Materials Research Department, has received the Statoil prize 1999.

Trainee mechanics Casper Hammershøj Olsen and Jesper Nilsson, of the Materials Research Department, have received The Metalworkers Medal.

Søren E. Larsen, Ph.D., M.E., of the Wind Energy and Atmospherics Physics Department, has been appointed Assistant Professor at the University of Copenhagen.

Staff 1997 - 2000

(Man years)

	Academic staff				Ph.D. and Post Docs				Others				Total staff			
	1997	1998	1999	2000	1997	1998	1999	2000	1997	1998	1999	2000	1997	1998	1999	2000
Programme areas	259	262	270	291	104	103	120	128	177	195	188	185	540	560	577	604
Of which: Heads	44	42	42	42									44	42	42	42
Senior scientists	125	142	138	143									125	142	138	143
Scientists	24	35	48	53									24	35	48	53
Other scientific staff	66	43	42	53									66	43	42	53
Ph.D.					55	57	65	67					55	57	65	67
Post Doc					49	46	54	61					49	46	54	61
Techn./adm. area	71	65	53	53					170	135	131	127	241	200	184	180
Nuclear facilities	12	13	13	12					70	64	65	65	82	77	78	77
Students and trainees									36	26	27	28	36	26	27	28
Total	**342**	**340**	**335**	**356**	**104**	**103**	**120**	**128**	**453**	**420**	**411**	**405**	**899**	**863**	**866**	**889**

Organisation and management

Board of Governors

Jørgen Mads Clausen, Managing Director
Danfoss A/S
Chairman of the Board with effect from 1 January 2000

Professor Ulrik V. Lassen, M.D.
Novo Nordisk Fonden
Chairman of the Board until 31 December 1999

Poul Skovgaard, Director
Vice Chairman of the Board with effect from 1 October 1999

Inge Thygesen, Senior Advisor
Ministry of Finance
Vice Chairman of the Board until 30 September 1999

Per Buch Andreasen, M.D., Dr.Med. Sc.
Copenhagen District Hospital, Gentofte

Adjunct Professor Kurt Nørgaard Clausen, Ph.D.
Head of Programme, Risø National Laboratory
Elected by Risø's personnel

Professor Knut Conradsen, Vice Rector
The Technical University of Denmark

Jørgen Elikofer, Management Secretariat
Danish Metalworkers' Union

Agnete Gersing, Director
Danish Institute of Agriculture and Fisheries Economics
With effect from 1 October 1999

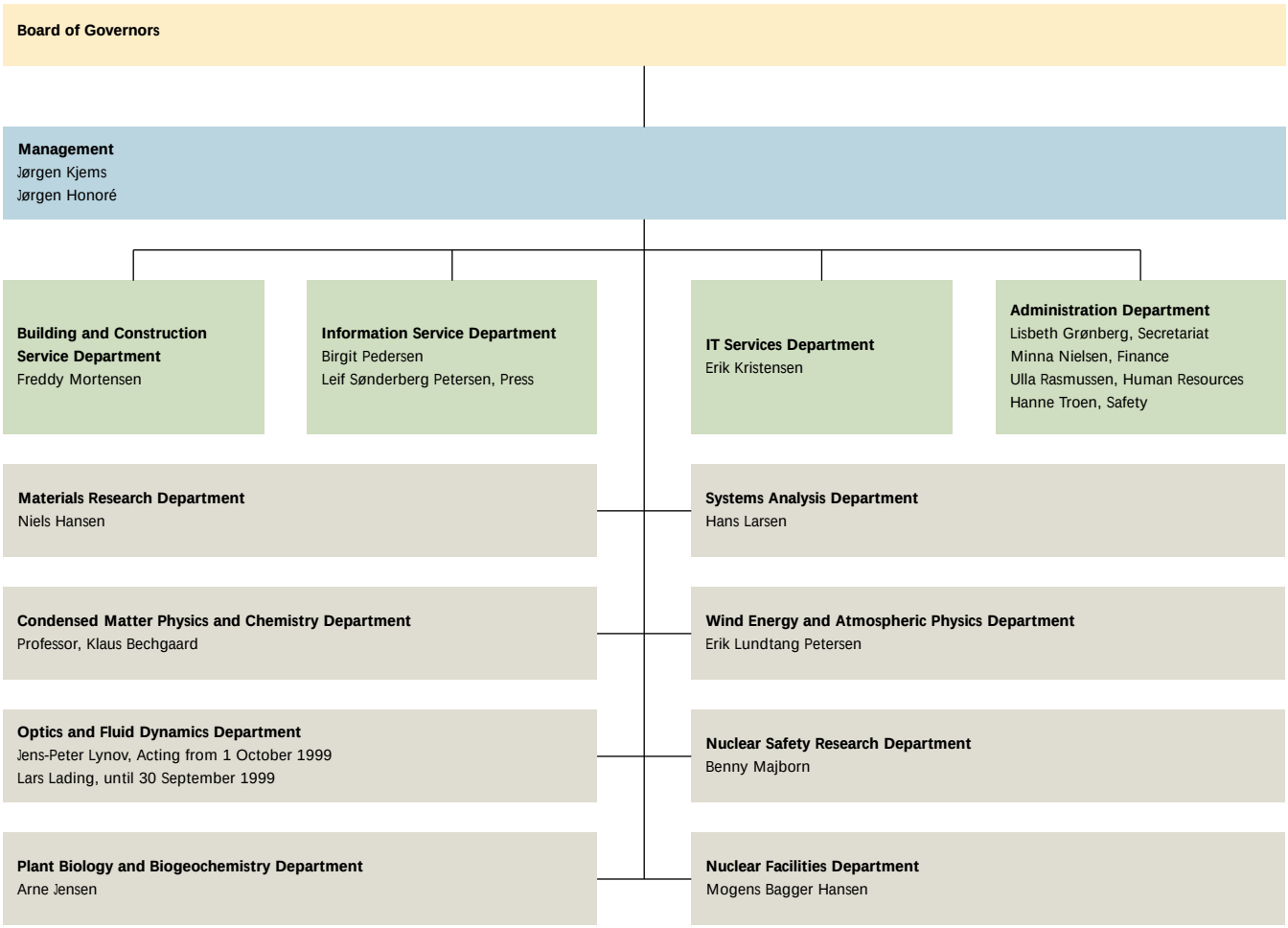
Jens Olsson, Research Technician
Risø National Laboratory
Elected by Risø's personnel

Birte Skands, Development Manager
VIKAS A/S

Annette Toft, Head of Department
Danish Agriculture Council
with effect from 1 February 2000

Secretary of the Board
Head of Secretariat
Lisbeth Grønberg, LL.M.

Risø National Laboratory

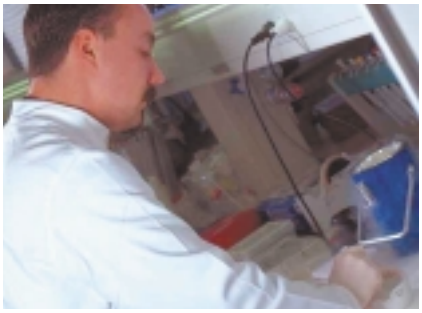


The Administration Department and the Nuclear Facilities Department were established by an organisational amendment on 1 January 2000.

Risø's large-scale experimental facilities

Risø's large-scale experimental facilities provide Danish scientific and technological research with special opportunities, acting as a catalyst for international interdisciplinary collaboration.

MICHAEL FISCHER



Ph.D. student Jock Nielsen studies how the fungus mykorrhiza transfers phosphorus to plants at the genetic level, thus helping to minimise the use of artificial fertiliser.

DR3 research reactor

Neutron radiation from the DR3 research reactor is used for many purposes, some of which have already been discussed in this report. The TMR programme is also being implemented, in a joint venture with Studsvik, Sweden. Its purpose is to make the neutron scattering facilities of the two institutions available to European researchers. The programme has EU funding until the middle of 2003. The DR3 research reactor is closed down every fourth year for a long total period of six to seven weeks for major inspection. According to plan, this would take place in the year 2000, but due to the repair of a leaking drainage pipe in the DR3 reactor tank, this extended closure was brought forward to December 1999.

RERAF

Several projects have been carried out in RERAF relating to CO_2 in the atmosphere, which stimulates plant growth to varying degrees. Utilisation of CO_2 also depend on the root formation of a plant and interaction with symbionts, for example mykorrhiza fungi, which increases the ability of a plant to absorb nutrients. Experiments show that plant growth has been restricted by carbon and not by nutrients. This means that CO_2 stimulates growth. Plants with mykorrhiza are better able to assimilate and utilise the extra carbon than plants without mykorrhiza, but the mechanisms behind the increase in carbon assimilation and utilisation are yet to be understood.

Brassica plants from fields representing different types of agricultural practices are cultivated in RERAF. These progeny will be analysed to assess their origin, and thereby the spread of genes/transgenes from oilseed rape (Brassica napus) to the weed field mustard (Brassica rapa). The spread of genes from transplastomic oilseed rape (plants with transgenes inserted into chloroplast DNA instead of nuclear DNA) to field mustard will also be assessed. The assumption is that genes from transplastomic oilseed rape cannot spread via pollen, but only via seeds. Thus, the only escape route for this type of transgenes to field mustard is when hybrids are produced with oilseed rape as the female parent. Since seeds spread more locally than pollen, this will reduce the gene flow considerably.

Laboratory for human–machine interaction

The interaction between humans and machines can be studied at a renewed laboratory, fitted with new equipment and modern analysis facilities. The laboratory is used in connection with evaluation and analysis of simulators, usability (checked with a native expert), human–machine interfaces and the work routines of individuals and teams. The new laboratory incorporates eye-tracking equipment, which makes it possible to register the visual attention of experimental subjects. In addition, there is a mobile usability laboratory, which makes it possible to carry out experiments anywhere, for example in a vehicle or on the bridge of a ship.

MICHAEL FISCHER

Ph.D. student Lise Arleth is using the small-angle neutron scattering instrument at Risø's research reactor DR3 to study various biophysical and physical-chemical systems.

MICHAEL FISCHER

In Risø's controlled environment, RERAF, experiments can be carried out on genetically modified plants, for example, under hermetically sealed conditions. This provides the setting for risk assessment of the spread of undesirable genes from genetically modified plants.

Collaboration strengthens Risø's activities

Danish and international collaboration stimulates the flow of new knowledge into Risø and out to our customers and collaboration partners. During the year 2000, a mid-way status will be undertaken focusing on this subject. It will include the results of technology transfer benchmarking from major research institutions, which is being undertaken under the auspices of the EU, as well as a targeted user survey among Risø's customers.

Collaboration with companies simplified

During 1999, eight types of collaboration were identified, which may form the basis for introducing new joint ventures between companies and Risø. The various types of collaboration are presented in a new booklet entitled "2x4 muligheder for danske virksomheder" ("2 x 4 opportunities for Danish companies"). The booklet was distributed to more than 1,000 Danish companies at the end of 1999.

The Danish Polymer Centre

As discussed in the introduction, Risø and DTU have joined forces to establish the Danish Polymer Centre.

Centre for miniaturisation of optical sensors

During 1999, Risø entered into a contract for a three-year Centre for miniaturisation of optical sensors (MINOS), supported by The Danish Agency for Trade and Industry, together with DELTA, the Institute of Technology, DTU and the following companies: Dantec Measurement Technology A/S, IBSEN Micro Structures A/S, Kamstrup A/S and Radiometer Medical A/S.

Control and regulation of industrial processes and systems

The Centre for on-line, non-contact monitoring, control and regulation of industrial processes and systems (BIPS), was initiated in conjunction with the FORCE Institute, DTU, Junckers Industrier A/S, Coloplast A/S, The Danish National Railway Agency and Hammel Maskinfabrik A/S. This centre was set up towards the end of 1999 and receives support from The Danish Agency for Trade and Industry.

Collaboration on biomedical optics

Risø and DTU have set up a joint research programme entitled Biomedical Optics (BIOP). The new venture may develop completely new biomedical applications using modern laser technology, including 3D tissue imaging, new methods for the diagnosis of eye diseases and diabetes, as well as new biosensors for concentration measurements of glucose and proteins, for example. The Danish university hospitals of Marselisborg and Herlev are also participating, together with the firms Torsana A/S, Nordic Laser Systems A/S, Asah Medico A/S and IONAS A/S.

Nanometer and micrometer scale material physics programme

DTU and Risø have set up a joint research programme entitled "Nanometer and micrometer scale material physics programme". This research programme aims at building at bridge between phenomena at nanometer scale and phenomena at micrometer scale, opening up new development possibilities for Danish industry and ensuring better utilisation of the research and experimental facilities of the two institutions. At the same time, it will be possible to offer education for graduate and undergraduate level.

Centre for Surface Analysis

Nine Danish companies and several research institutions have joined forces with Risø to establish the Centre for Surface Metrology and Functionality. The Centre, which is provisionally scheduled to be involved in a large number of surface technology development projects over the next three years, is supported by DKK 16.4 million from The Danish Agency for Trade and Industry. The nine companies are contributing a total of DKK 21 million. The Centre aims to develop advanced measuring methods for the quantification of chemical, physical and tribological properties of industrial surfaces for the purpose of optimising the functional properties of materials, e.g. their durability, corrosion and smoothness.

Centre for Analysis of Environment, Economy and Society

The Centre for Analysis of Environment, Economy and Society was established in 1999 by integrating activities at DMU and Risø. It aims to expand the research environment as well as exploiting the synergy between related areas of research. The centre researches environmental economy, integrated environmental information systems, assessment and forecasting of emissions as well as sector analysis in the areas of land use, transportation and energy.

Management of research processes

REMAP is a new, interdisciplinary venture of Risø and the Department of Management, Politics and Philosophy at the Copenhagen School of Business, The Danish Institute for Studies in Research and Research Policy and the companies Danisco A/S, TeleDanmark A/S, Haldor Topsøe A/S, NKT Research Center A/S, Reson A/S and Dansk Drogeanalyse A/S. The project is financed by the participants and the SUE programme of the Danish Research Agency. The project aims to develop an integrated model for understanding management, setting priorities and the evaluation of complex research processes in private and public sector research and development. The venture also aims to strengthen the interdisciplinary exchange of results and experience between the institutions and the companies and to create collaboration in the training of scientists, the mobility of scientists and teaching at graduate level.

Collaboration on type approval of wind turbines

During 1999, Det Norske Veritas and Risø have entered into a collaboration agreement on type approval of wind turbines. The new joint certification unit will provide service and competence to the wind turbine industry, investors and insurance companies. In the venture, DNV is responsible for the implementation of type approvals and Risø is responsible for the development of type approval activities such as the basis for approval. Both partners will contribute equally to the venture. A joint board has

In order to maintain Risø's international standing, research must be undertaken in collaboration with leading scientists and institutions abroad. Collaboration at the international level features frequently in the project descriptions contained in this report. Here are a few more examples.

been set up for the venture. Legally, the venture is organised under the auspices of DNV.

New welding method

An example of new projects under the Fifth Framework Programme of the EU is the new welding method Friction Stir Welding, in which welding is done by means of a rotating tool that fuses the materials together using a friction principle. The advantage is that high strenght light metal alloys retain the mechanical properties that they were developed for. Risø is participating in two EU projects, in one project serving as co-ordinator of the scientifically oriented joint venture with partners including DaimlerChrysler, FIAT and a major European welding institute. In the second project, British Aerospace, Airbus, is leading a more technologically-oriented joint venture of 13 European partners; here, Risø's task is to measure residual stress using Risø's neutron radiation facility.

Forests help to counteract greenhouse effect

More than three years of continuous measurements of the exchange of CO_2 between forests and the atmosphere, carried out at a field station in an old beech forest near Sorø, show that carbon is stored in the ecosystem. The annual uptake of carbon is highly variable and is less than anticipated. Thus, the forests of the world are not necessarily as large a sink of CO_2 in the atmosphere as previously believed. In the much longer term, the uptake of carbon may be followed by efflux, but in the short term (100 years), an increase in afforestation could represent a significant sink. The field station forms the basis of Risø's participation in international collaboration on element cycling in forest ecosystems. The international EU-financed research projects are concerned with the exchange of carbon, nitrogen and ozone between the atmosphere and the forest ecosystem. In the context of a project under the auspices of SMP, the field station was expanded to incorporate measurement of transport of solutes in rainwater and groundwater. Measurements of carbon exchange between the atmosphere and the forest have shown that the variations in the net absorption of carbon from one year to another are mainly due to climatic differences. The station will now be used and further developed in two more projects under the auspices of the Fifth Framework Programme of the EU. One project is concerned with measurements of carbon dioxide exchange at 20 stations in Europe; the other project studies the interaction between element cycling and climate and is part of a network of four stations.

Methods of measuring aircraft pollution

The increase in passenger traffic in our common airspace has brought into focus the consequences of pollution from aircraft during flight. Risø is contributing to the EU-project Aeroprofile with the development of advanced measuring methods for non-contact measurement and mapping of exhaust gases in test facilities and during flight. During 1999, Risø has developed methods that make it possible to use inexpensive, commercial equipment for pollution measurement in future.

International mapping of airborne plant diseases and disease resistance in cereals

A six-year European joint venture was concluded during 1999. It had been initiated and managed by Risø and concerned population studies of airborne diseases in cereals. The intention was to come up with improved disease control strategies. The joint venture took place through a COST network of researchers and plant breeders from some 80 institutions in 23 countries. The venture considered the economically most significant leaf diseases of barley and wheat and resulted in close European co-ordination at many levels for future research initiatives, monitoring and understanding the spread of disease and developing more resistant cereal cultivars.

Collaboration on the results of nuclear accidents

Risø has undertaken extensive intercalibration of national network monitors with the participation of scientists from a number of EU member states. This work, which is being carried out under the EU EURADOS research programme, demonstrates the need to undertake these types of intercalibration exercises on a regular basis in order to ensure uniform measurements of natural radiation levels within the EU.

IAEA chose Risø's methods

IAEA has chosen to use Risø's methods for cleansing a built-up area in one of the most highly radioactively polluted areas in Belarussia. There are plans subsequently to set up a research laboratory in this area. The work, led by Risø scientists, was followed up by an IAEA seminar for 60 cleansing specialists from Russia, Ukraine and Belarussia.

MICHAEL FISCHER

Ph.D. student Lars Eriksen studies the fungus *Mycosphaerella graminicola*, which causes the disease septoria tritici blotch on wheat. By learning more about the fungus that causes the disease, better strategies for disease control, using resistant cultivars and lower input of fungicides can be devised.

Acronyms and abbreviations

Aeroprofile	EU-project: Profiling spectrometry to simultaneously investigate the spatial distribution of temperature and chemical species in Aircraft Exhausts
COST	European co-operation in the field of scientific and technical research
DJF	Danish Institute of Agricultural Sciences
DTU	The Technical University of Denmark
EFP	The energy research programme of the Danish Ministry of Environment and Energy
ESRF	European Synchrotron Radiation Facility, Grenoble
EURADOS	European Radiation Dosimetry Group, EU programme
EURATOM	European Atomic Energy Community
IAEA	International Atomic Energy Agency
IPCC	Intergovernmental Panel on Climate Change
KU	The University of Copenhagen
KVL	The Royal Veterinary and Agricultural University
MeV	Million electron volts
NBI	The Niels Bohr Institute, The University of Copenhagen
PAH	Polycyclic Aromatic Hydrocarbons
PSO	Public Service Obligations
REMAP	R&D Management Processes under Rapid Changes
RERAF	Risø Environmental Risk Assessment Facility
SDU	University of Southern Denmark
SMP	The Danish Strategic Environmental Research Programme
SNF	The Danish Natural Science Research Council
SOFC	Solid Oxide Fuel Cell
SUE	Joint venture involving sector research, the universities and industry
VKI	Institute for the Water Environment

BERT WIKLUND

Risø and New and Renewable Energy Authority (NREA) in Cairo together operate 21 meteorological stations in Egypt for the Wind Atlas for Egypt. Pictured here is a recently erected 30-MW wind farm near Zafarana, Egypt.

Mission

Risø's purpose is to carry out research in the natural sciences and technology, affording Danish society new opportunities for technological development. The research is carried out in areas where Risø either has, or can achieve, an independent position nationally, and international impact.

Research is targeted towards areas of application that contribute to strengthening the competitive edge of Danish industry and reducing the impact on the environment of the industrial, energy and agricultural sectors.

Risø has special responsibility for consolidation of the knowledge base for the provision of consultancy on nuclear issues. Risø is also responsible for the treatment and temporary storage of Danish low and medium level radioactive waste.

Risø provides consultancy to government authorities on issues lying within the research institution's areas of activity.

Risø operates major experimental facilities for the benefit of Danish and foreign users. Risø's research is intended to serve as a basis for active participation in the training of scientists. Risø is able to participate in research programmes at home and abroad and can accept paid R&D and consultancy assignments for the private and public sectors within the centre's areas of activity.

It is our hope that reading this annual report will show that we live up to the goals and parameters that have been set for Risø's activities.

Risø's activities in 1999 are reported in the following publications: Risø Annual Report (available in Danish and English), Risø's Annual Performance Report (Danish), Risø's Publication Activities (Danish/English), as well as the annual progress reports of the seven research departments (English). All publications and further information can be obtained from Risø's webserver, www.risoe.dk.
Printed publications are available from the Information Service Department,
tel.: +45 4677 4004, e-mail: risoe@risoe.dk,
fax: +45 4677 4013.

Back cover:
Pictured here are some of the 29 participants in the fuel cell programme, gathered around the encouraging result of the latest development in cells, a large, flexible, strong cell of more than 500 cm^2.

Photo: Boye Koch

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